Report of the industrial transformation workshop in the South Asian region

(Proceedings of the workshop held on 4 and 5 April 1998 in New Delhi, India)

Organized by
TERI

In association with
Global Change Systems for Analysis, Research and Training

Asia–Pacific Network for Global Change Research

© Tata Energy Research Institute 1999

TERI Report No.97PG49

All rights reserved. No part of this publication may be reproduced in any form or by any means without prior permission of the Tata Energy Research Institute

Prepared by
Tata Energy Research Institute
Darbari Seth Block, Habitat Place
Lodhi Road, New Delhi – 110 003, India
Telephone: 91 11 460 1550, 462 2246
Fax: 91 11 462 1770, 463 2609
E-mail: mailbox@teri.res.in
Web site: http://www.teriin.org

Contents

Acknowledgements **vi**

Introduction **1**

Industrial transformation in Asia: emerging issues for further research **3**
Pradeep Dadhich and DSRK Srinivas

Macroeconomic issues related to IHDP-IT **45**
Sreekant Gupta

Consumption of energy and materials in South Asia **51**
Leena Srivastava

Panel discussion

International issues related to IHDP-IT **57**

Issues in industrial transformation in South Asia **65**

Appendices

Rural ecological engineering for refinement of energy use through renewable energy technologies **83**

Material flow and recycling approaches for steel, paper and pulp, and coal **91**

Programme **99**

List of participants **101**

Acknowledgements

TERI would like to gratefully acknowledge the support and guidance offered by the IHDP-IT (International Human Dimensions of Global Environmental Change Programme – Industrial Transformation) scientific planning committee for organizing this conference. TERI's heartfelt thanks to the Asia–Pacific Network for Global Change Research and START (Global Change System for Analysis, Research and Training), USA whose financial support made this conference possible.

TERI would like to make special mention of Mr Pradeep Dadhich for editorial inputs, Ms V Annapurna and her team for providing key organizational support, Ms J Ram Mohan for copy-editing, Mr T P Sankar for design and layout, Ms Veena and Ms Honey Taluja for secretarial help.

Special thanks are due to Dr R K Pachauri for his indispensable guidance, and other friends and colleagues at TERI for their support.

Introduction

Background

The industrial transformation research agenda is about understanding the human drivers and mechanisms that could enable a transformation of the industrial system towards sustainability and, in physical terms, to decouple industrial activities from their environmental impacts. It includes research efforts describing the patterns (over space and time), organization and technology of production and consumption of manufactured goods and services, their natural and energy transformations and associated environmental impacts, and the consequences of these impacts on the quality of life.

An extensive network on industrial transformation was developed during the course of 1996/97. Several other achievements in the further development of IHDP–IT (International Human Dimensions of Global Environmental Change Programme–Industrial Transformation) took place during the same year. At the international open science meeting in Amsterdam on 20 February 1997, the Inventory of Research report was endorsed. The report described industrial transformation and the research going on in this field. In June 1997 a research-planning group was established. This group drew up a research agenda. The regional workshops are a part of the IHDP-IT programme to generate research ideas and focus more on regional issues in industrial transformation.

The workshop in South-Asia was organized by TERI and supported by START (Global Change System for Analysis, Research and Training) and APN (Asia-Pacific Network for Global Change Research).

The broad scope and mandate of the South Asian regional workshop was to

1 discuss and consider the existing research inventory, the overall goal of the IHDP research activities;
2 develop ideas, set priorities, and make proposals for a research agenda on IHDP-IT, both at the global level and the regional level; and
3 explore contributions, including funding for the implementation of the prioritized research activities.

Research fields that were discussed at the workshops include

1 macro-systems, such as the environmental Kuznets curve, international mass balance analyses, fiscal and financial incentive structure, trade issues, etc.;

2 industrial ecology, including life cycle analysis, eco-design, industrial networks, organizational aspects, etc.; and
3 consumption including consumer needs and preferences and the role of the consumer in decision-making.

Participants

Participants in the regional workshops were representatives in each of the three fields mentioned above. Moreover, representatives of the industrial production and consumption sectors including R&D institutions and universities also participated. Government representations were from the ministries of science, environment, and economics.

Outcome of the workshop

Several ideas were proposed during the two days of the workshop. This report contains the main paper that was prepared by TERI, two keynote addresses and the two proposals which were generated from the workshop. The two proposals are (1) Materials flow and recycling approaches for steel, paper and pulp, and coal analysis and (2) Rural ecological engineering for refinement of energy use through renewable energy technologies.

Industrial transformation in Asia – emerging issues for further research

Pradeep Dadhich and D S R K Srinivas, TERI

Introduction

Over the years, it has become apparent that the major task before us is to achieve a balance between environmental protection and industrial development. The long-term prospects for industrialization and development in the developing countries to the current levels of affluence in the industrial world are clouded by the untenability of the resource and pollution burden it will impose on the planet's ecosystem. In the immediate term (say a couple of decades), however, there appears to be considerable scope for incorporating an accelerated introduction of energy efficiency and cleaner technologies as an integral part of the development process. Therefore, there is a great need for realizing this potential and acting accordingly to help orient the development in an environment friendly manner. Problems relating to economy, pollution, and consumer needs arise while accomplishing these. A great deal of effort, in terms of research, planning, and implementation, in a well-coordinated manner needs to be put in so as to shape the process of industrial development with the least impacts on the global environment.

The IHDP (International Human Dimensions of Global Environmental Change Programme), Germany, initiated in 1990 by the International Social Science Council, fosters research-related activities that seek to describe and understand the human role in causing global environmental change and the consequences of these changes for society. IT (industrial transformation) has been identified as one of the six priority research topics within IHDP. The ultimate aim of IHDP-IT is to understand the human drivers and mechanisms that could enable a transformation of the industrial system towards sustainability and, in physical terms, to decouple industrial activities from their environmental impacts.

Industrial transformation encompasses all research efforts related to describing the patterns (over space and time), organization and technology of production and consumption of manufactured goods and services, their material and energy transformations and associated environmental impacts, and the consequences of these impacts on the quality of life.

However, the need to prioritize the most pressing issues that highly influence the environmental conditions and development cannot be overemphasized in the process of prioritizing efforts towards industrial transformation.

Energy in South Asia and the emerging environmental issues

The most important and abundant source of energy in the Asia and Pacific region is coal, followed by fuel wood and natural gas. Power is another major input to industry and development.

To fuel the rapid growth of Asian economies, electricity generation in the region is forecast to grow at an annual rate of 6.5% up to the year 2000 and at an annual rate of 5.3% between 2000 and 2010. Coal combustion is currently the main source of electricity production, and it accounts for 80% of Asia's coal consumption, which for the region as a whole is some 2 BT per year. Coal use will continue to rise at an annual rate of 3.7% per year to reach 3.1 BT by 2010 because of its abundant availability and cost advantage.

In many Asian countries energy production is inherently inefficient and wasteful due to lack of funds that would enable them to acquire the latest most environmentally-benign technologies, inadequacies in the institutional arrangements for energy (particularly the utilities), and energy pricing policies which fail to factor in the true cost of production.

However, coal combustion is the source of many pollutants, including SO_2, NO_x, and dust, and accounts for 80% of SO_2 emissions and acid rain in Asia. Whether Asia succeeds in reducing SO_2 emissions and other energy-related pollutants will depend critically on the availability and cost of clean coal technologies.

Coal and its use in the various industrial sectors including power generation qualifies for selection to the IHDP-IT programme because of its significant contribution to global environmental system by way of climate change and resource depletion. The combustion of coal also causes regional problems that could, over time, develop into global problems because of acid rain and other human and ecological related problems.

Coal markets

In an expanded coal-use scenario, potential inter-regional coal markets exist. Imported coal, despite high transport costs, is generally competitive in some parts of Asia and southern India. Regional production has not kept pace with consumption despite large coal reserves. Thus, the South Asian region could likely be a net coal importer.

Non-CO_2 environmental impacts of coal production and use

Coal has always been an inexpensive fuel in terms of its cost per joule of energy. It has also always been an expensive fuel in terms of its associated non-fuel costs, especially its capital costs. In addition, virtually every stage of coal production and use creates by-products which can adversely affect the environment. These range from gases and particles released into the atmosphere to mine wastes and other discharges. Coal production and consumption processes have coincident environmental hazards, which are associated with virtually every class of environmental degradation. The abatement of pollution related to coal use has added significantly to the costs of combustion. Pollution penalties, if introduced, can be a potential barrier to world coal penetration.

Coal reserves

India is relatively well-endowed with both exhaustible and renewable energy sources. Coal is the major exhaustible energy resource in the country and has a life expectancy of over 200 years. The total coal reserves have been assessed at about 202 BT of which 15% is coking coal and 85% non-coking coal. Of the non-coking coal reserves, 85% is inferior grade (GCV < 5000 kCal/kg) mostly suitable only for power generation. Sixty-three per cent of the total coal reserves occur within 300 m depth in thick interbanded seams. The bulk of the reserves are amenable to opencast mining.

Coal production

The coal industry was nationalized in two stages – coking coal mines were taken over in October 1971 and all other coal mines in January 1973. This was done, apart from other considerations, with a view to ensure that the production of coal, which is the primary source of energy, should be properly planned to meet the increasing requirements for the industrial development of the country.

To ensure sustained and planned development of all facets of the coal industry, massive investment to the tune of about 180 billion rupees has been made since nationalization in opening of new mines, re-organization of existing mines, and development of associated infrastructure. Coal production has registered an annual growth rate of about 4.3% since nationalization, increasing from a level of 73 MT (million tonnes) in 1970/71 to 270 MT in 1995/96. In the post-nationalization period, the major thrust was towards the development of new outlying coalfields, which contributed 45% of the total coal production in 1995/96. Consequent to the development of new coalfields, a large number of pithead super thermal power stations have come up. This has helped in reducing the load on railways as most of these pithead power stations transport their coal by captive modes such as merry-go-round (unit train) system.

The large increases in production could be achieved through enhanced investment in the coal industry by the government, deliberate shift in technology, increased emoluments and welfare amenities for coal workers, and other measures. The opencast mines which contributed only about 28% of the total production at the time of nationalization (1973) increased their share to about 72% in 1995/96. The major factors in favour of opencast mines are shorter gestation period, high recovery and safety, and lower cost of production. However, the bulk of coal produced from opencast mines is inferior grade coal. As a result of this policy, the production of inferior grades of both coking and non-coking coal has been increasing in the last two decades.

Coal consumption trend

Coal consumption has increased from about 72 MT in 1970/71 to 280 MT in 1995/96. The electricity sector is the single largest consumer of coal (70%), followed by the iron and steel (15%) and cement sectors (4%). Indigenous coal production, by and large, meets the country's demand except that of the steel sector. The demand for washed coking coal for the steel plants in recent years has far outstripped the indigenous supply both in terms of quality and quantity. The existing washeries are old and unable to meet the demand in terms of quality of supplies (<17.5% ash content in coal). Therefore, 9 MT of low ash coking coal is imported annually by the steel plants for meeting their demand. Cement has emerged as the third largest coal consuming sector. The coal consumption by all other industries was around 10% of the total coal consumption.

Coal demand

The Working Group for the Ninth Plan constituted by the Ministry of Coal, Government of India, has assessed the coal demand to grow at an average annual rate of six per cent. Based on this, the coal demand for 2011/12 is about 835 MT. If energy conservation measures are adopted in all the consuming sections, the demand would reduce to 554 MT in 2011/12 (a TERI estimate).

Existing technology for coal production

The technology options, opencast or underground mining, are driven by geological, technical, and commercial considerations. Opencast mining is almost always cheaper than underground mining. The coal extraction percentage is much higher in opencast mining (90%), as against 30%–40% in underground board and pillar mining, which is the most prevalent technology in Indian mines. In addition, while thick seams are a definite advantage in opencast mines, they represent a serious challenge in underground mines. Many thick seams developed on board and pillar method of mining are standing on pillars because of lack of proper technology to extract the pillar. The other advantages of opencast mining include increased safety of operations and lower gestation period. The specific investment per tonne of coal is also comparatively lower than that for underground mines.

The coal industry is currently using shovel, dumper, and drag line for winning and transportation of coal and overburden. In lignite mines, bucket wheel excavator, cross pit and around the pit conveying system, and stacker or reclaimer are used for continuous excavation and transportation of lignite and overburden. Present environment management practices in coal mines are backfilling, compaction by shovel dozer for overburden dump, water spraying for dust suppression, and settling tank for water treatment.

Resource requirements for the coal cycle

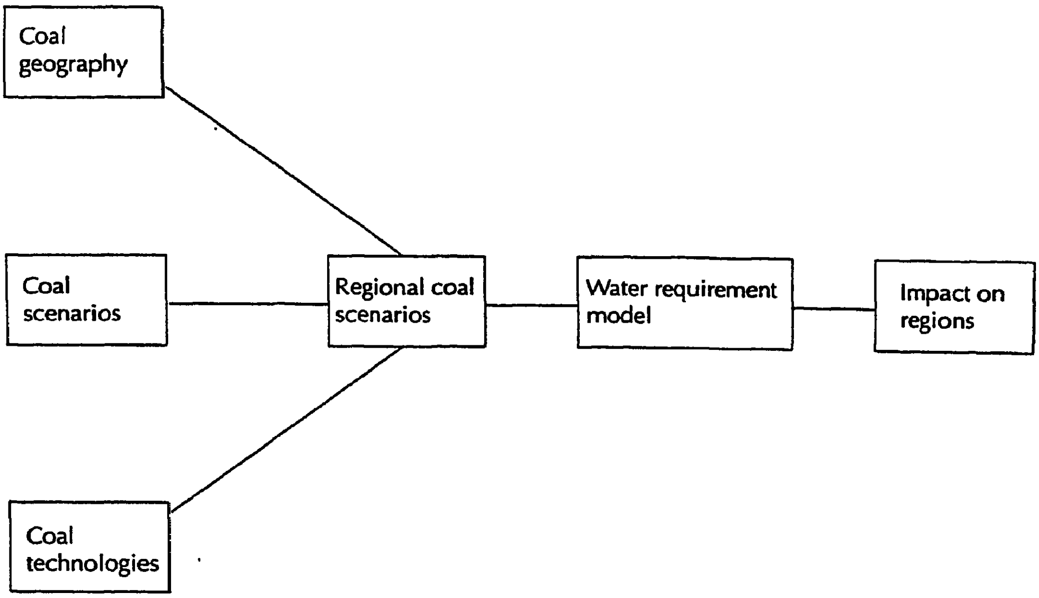
Water, energy, materials, manpower, and land are the total resources consumed in the coal cycle, which includes coal mining, coal conversion, and further use. To assess the range of natural (and other) resources required to achieve access to a desired quantity of an energy resource like coal, it is necessary to evaluate the factors outlined in Table 1.

Table 1 Characteristics for resource and environment evaluation

Resource characteristics	Environment characteristics
Location and extent of deposit	Geology, stratigraphy
Deposit parameters: type, geology, quality, etc.	Land: topography soil, existing use, planned future use
Exploitation: type of mining, equipment	Water storage, geology quantity, quality, current use, future demand

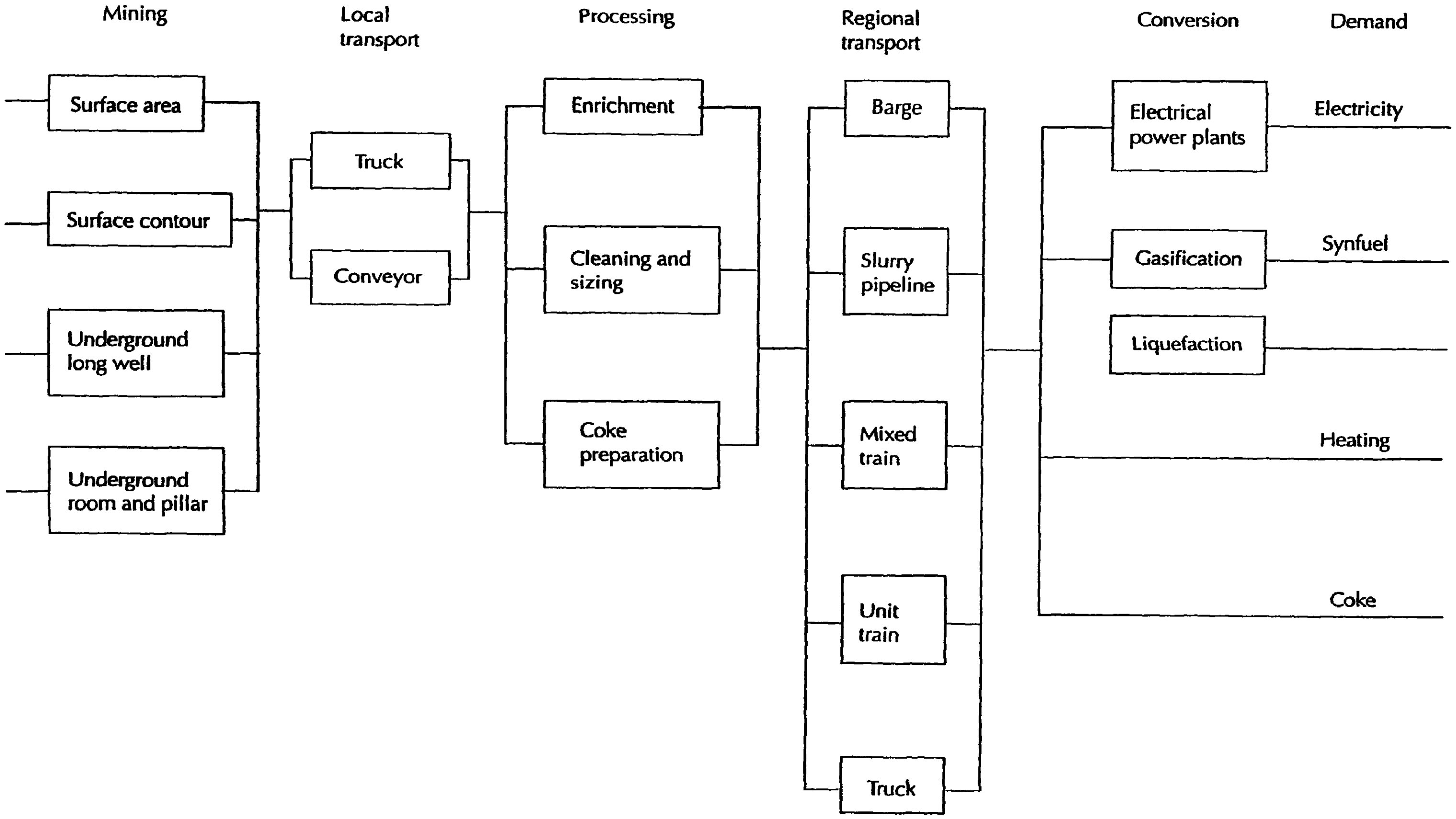
In 1984, Alcamo had attempted a comparative evaluation of the quantity of water required to expand coal production fivefold in North America (the US and Canada) (Chadwick, Highton, and Lindman 1987). The water requirements for future coal development will depend on the kind of technology that would be used in the future and it was not obvious what these technologies would be. Th methodology he adopted was as follows. Having decided on the coal scenario (Figure 1), the model was used to evaluate the water needed for such a development and was compared with an estimate of water available. He arrivec at the conclusion that a fourfold expansion of coal production would be constrained by the lack of readily available water. Figure 2 shows that in order meet a 'demand', a path or 'chain' must be followed through each of the six major coal sectors namely, mining, local transport, processing, regional transports, conversion, and demand. As Figure 2 shows, there are several possible technologies for each of these sectors.

Figure 1 Analytical approach to determining the impact of coal development on water resources



Two types of mining are distinguished: surface and underground. Underground mining is, in turn, subdivided into two categories, long-wall and room and pillar. The latter is by far the most common type of underground mining in India, whereas long-wall is the predominant method used in Europe and former USSR. Hydraulic mining is now being discussed as an alternative to long-wall mining but its future share of total underground mining is still unclear.

Figure 2. Selection of technologies for the coal industry in the future



'Local transport' refers to the movement of coal between mining and processing centres, which are often in close proximity. Two forms of local transport are included - truck and conveyor.

Three alternatives are specified for coal processing (1) enrichment facilities for low-grade coals destined for power plants; (2) cleaning and sizing facilities for higher-grade coals used in power plants or for residential or commercial heating; and (3) coke preparation for coking and other industrial coals.

'Regional transport' represents the distribution of coal from processing centres to either conversion facilities or demand centres. Five different transport modes are selected: barge, slurry pipeline, mixed train, unit train, and trucks. A 'mixed train' refers to a train that carries non-coal cargo in addition to coal. A 'unit train' carries only coal. Both types are currently used for short-distance haulage to conversion facilities or to other transportation modes.

Figure 2 specifies two possibilities for coal conversion – electrical power plants and liquefaction. Power plants are assumed to be of the conventional combustion type. Liquefaction plants are assumed to use the synthoil process. Synthoil consumes about the same amount of water as other feasible hydrogenation processes.

The last sector, demand, specifies four possible forms of energy from coal – electricity, synfuel, heating (which includes electrical production via cogeneration), and coke (which includes all industrial uses of coal, including feedstock). The purpose of coal conversion is the production of alternative fuels (including motor fuels) or the generation of a range of chemicals from coal by process routes such as gasification, direct and indirect liquefaction, hydro pyrolysis, and plasma pyrolysis. The application of these techniques is essential if the large reserves of coal are to be substituted for less plentiful fuels. The process by which such conversion can be brought about are gasification and direct and indirect liquefaction. Definitions of these complex process are given in Table 2.

Table 2 Definition of various processes used in coal gasification and liquefaction

Gasification	Complete conversion of the organic matter of coal into gases (used for reduction, chemical synthesis, and combustion)
Liquefaction	Conversion of as much as possible of the organic matter of coal into liquid products (used as fuels, gasoline, chemicals)
Process route 1	Direct liquefaction - hydrogenation of coal at high pressure
Process route 2	Indirect liquefaction - gasification of coal and consecutive catalytic conversion of the synthesis gas

The essential feature of coal conversion by gasification and direct or indirect liquefaction is the conversion of coal into higher-grade products (Figure 3) such as fuel gases, motor fuels, and chemicals, which, at present, are mainly produced from oil and natural gas. The main product routes for raw gases from coal gasification are shown in Figure 3. Simple purification and treatment of raw gas yield a hydrogen-enhanced reduction gas and a lean gas for combustion. By additional methanation, town gas and substitute natural gas can be produced. By an industrial scale, methanol is produced and can be used as a solvent, motor fuel, and feedstock for chemical industries (e.g., for the production of lead free anti-knock agents such as 'MTBE', acetic anhydride, and polyvinyl acetate). Most likely near applicability of methanol is the large-scale production of motor fuel and power generation. Further processing of methanol by the MOBIL process gives knock-proof gasoline and, under different reaction conditions, chemical products such as olefines. These technologies are being developed. Synthesis gas is also the basis for NH_3-synthesis and the oxo-synthesis in which aldehydes are produced from olefines.

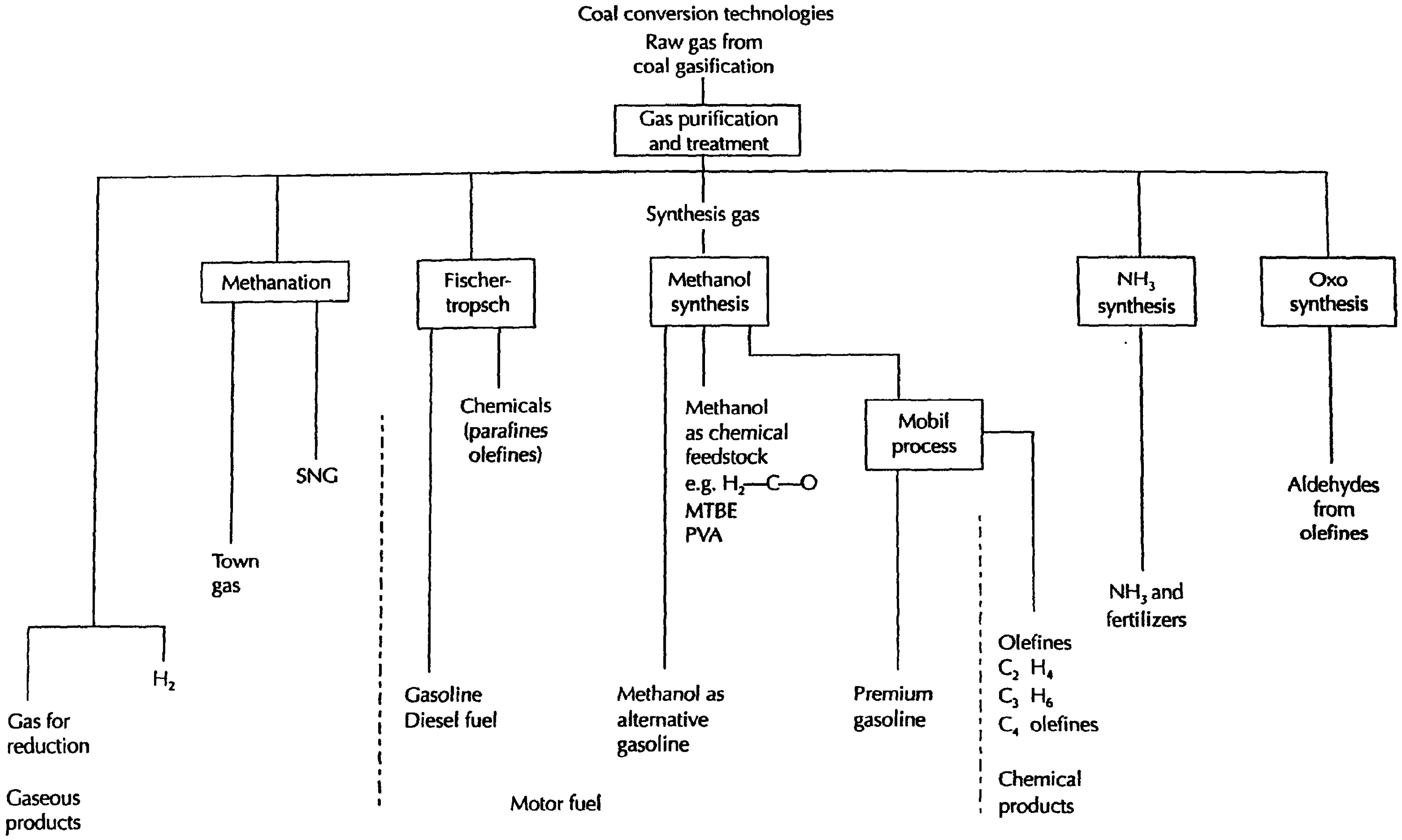
Environmental impacts

Mining activities lead to various environmental problems related to air, water, and land, apart from affecting human health. Mining activities in many cases affect the groundwater availability in the surrounding region by lowering the water table. During mining, the various operations lead to the generation of fine dust particulates which deteriorate the ambient air quality in and around the mining areas. A large amount of overburden dumps generated during opencast mining not only occupy a large portion of land but also deteriorate the soil and groundwater quality by surface run-off and water seepage, and causes safety problems in the area. Proper land reclamation practices, both technical and biological, need to be adopted during planning and execution of mining for proper dump management to improve its productivity, ecological integrity, and economic and aesthetic value.

Occupational and environmental health problems

Health risks from coal arise from all stages of the coal fuel-cycle: prospecting, mining, beneficiation, transport, storage, and utilization (direct combustion or following conversion to liquid or gaseous fuel). Health risks are part of the

Figure 3. Gasification and indirect liquefaction: production of fuel gases, gasoline, and chemicals



general environmental impacts that occur to natural, semi-natural, and man-managed environmental systems. These include long-term and far-reaching impacts such as the effect global emissions of CO_2 from coal burning will have on ambient temperatures and hence climate; the impacts of a local and regional nature arising from sulphur and NO_x emissions. Both will affect natural ecosystems (oceans, lakes, and terrestrial ecosystems); semi-atural ones (grasslands and forests); and man-managed ecosystems (agricultural, horticultural, and silvicultural).

Health effects due to the coal fuel-cycle are experienced by human populations either as part of the workforce (occupational health risks) or as the general public (public health risks). It is usually relatively simpler to determine the size of the working population that is at risk than to estimate with any accuracy the size of the exposed general population that runs the risk of some degree of hazardous exposure.

Global environmental aspects

The environmental problems associated with coal production are, for the most part, site specific and controllable with today's technology. A more serious concern and uncertainty exists over the air pollutants emitted during coal combustion. The effects of coal-induced air pollution are more widespread than the localized coal mining disruptions. Furthermore, the air pollution control technologies utilized in one area can actually intensify the level of pollution in another. In order to minimize the effect of emissions on local areas, utilities have used tall stacks to disperse gases and particles. Due to prevailing wind patterns and atmospheric conditions, these pollutants can be transported and deposited on other areas, creating both national and international air pollution problems.

The emissions from coal combustion include sulphur, nitrogen, and particles of ash. Once released into the atmosphere, these emissions mix with other natural and man-made gases and particles, making it difficult to distinguish the effects of one type of gas or particle from another or to determine the primary source of the pollutants. Despite these uncertainties, emissions from coal combustion are believed to be major contributors to air pollution. More than half of the world's man-made sulphur emissions are attributed to this cause. These sulphur emissions, as well as nitrogen and particulate emissions, are associated with human illness and death and the creation of acid rain leading to damage of plants, animals, and fish.

Therefore, the issues of concern are the emissions resulting from the burning of coal, which contribute significantly to global climate change; and the imbalances in the supply of and demand for energy, not only in the urban areas, but increasingly in rural areas as well.

Industrial transformation in South Asia

At the global level, IHDP has identified industrial transformation as one of the six priority research topics. On the basis of discussions held at the international workshop on IHDP-IT, organized by the Institute of Environmental Studies of the Vrije Universitiet, Amsterdam, the following major research areas were outlined.

- System-analytical perspectives such as the environmental Kuznets curve, international mass balance research, eco-restructuring, and developed–developing country interactions.
- Industrial ecology including industrial networks, eco-efficiency, life cycle analysis, greening the industry, and organizational issues.
- Consumers, including consumer choice issues and the role of consumers in decision-making.

As has been studied, the most important and abundant source of energy for industries and power generation in the Asian region is coal, which will continue to be the main energy source for most of the countries in the region. Therefore, any attempts to retard environmental degradation will have a large bearing on the power and coal sectors. Iron and steel and cement will be the major coal consuming sectors in the future. Focus on the technological and environment aspects of these sectors should be included in the research areas from the industrial transformation point of view.

Potential areas for focusing research efforts on IT

Technological developments and the associated economic and environmental implications form the major guiding factors for considering the future directions. The latest economic policies of the South Asian region indicate that the thrust will be on further liberalization of industrial, trade, and financial policies to increase efficiency and productivity, and expand access to international markets.

TERI carried out a study titled Growth with Resource Enhancement of Environment and Nature - 'GREEN India 2047', whose objective was to identify negative impacts on the environment that has been steadily deteriorating. The impacts on air, water, and land were studied. The biodiversity aspects and the impacts of pollution in cities and the loss of natural wealth in the countryside were also included in the study. The study tried to examine questions like (1) What is the extent of damage in physical terms? (2) What are its causes, both direct and indirect? (3) How many billions has the damage cost us? (4) Does the price of economic development have to be a deteriorating environment? (5) What can be done to reverse the degradation?

The first phase of the project sought to set forth the extent of degradation of India's natural resources during the first 50 years of its Independence and to assess the damage in economic terms. The results were comprehensively documented by a team of TERI researchers in a 350-page volume, which was presented to the Prime Minister of India. The study also indicates that the primary goal of a society like India is to promote economic growth and development which will remain paramount for quite some time. The study indicated that growth which is pursued in the mould of past structures and activities would actually be inhibited in due course because the natural resources which sustain and provide environmental services for various economic activities - largely unpriced in the market - would actually decline in quality and quantity, such that output itself would suffer.

Sustainability concerns

The objective of the next phase of the 'GREEN India 2047' project is to articulate policies, measures, and strategies by which a smooth but rapid departure is brought about from past trends and practices, so that the Indian economic system and its basic structure become truly sustainable. It is first necessary to get an assessment of some growth projections for the future, which are attempted on the assumption of a business-as-usual scenario. The projections of population, gross domestic product, and sectoral growth rates that were arrived at, based on current trends of consumption and production, are staggering.

For instance, based on current patterns of development, the total production of finished steel in 2047 would be approximately 260 MT; of aluminium, 7.6 MT; of cement, 1303 MT; and of nitrogenous fertilizers, 27.3 MT. In some cases, the total growth in the next 50 years based on a business-as-usual scenario would be higher. For instance, the increase in production of steel would be more than tenfold; in the case of cement, almost fifteenfold; and in the case of cotton textiles, the increase would be more than eightfold. Agricultural production also is expected to increase on a large scale during this period but somewhat slower than the expected growth of the industry. Overall, during the period 1990–2047, the GDP (gross domestic product) is projected to grow at a cumulative average of 5.3% annually and agriculture at 2.2% a year. The share of agriculture in the GDP would, therefore, come down from 31.3% to a little more than 5% by the year 2047 while the share of industry would go up during the same period from 28.7% to 40.3%. The services sector would also increase its share from 34.6% to 47.4% [Pachauri (in press)].

The Indian power sector

The 15th Electric Power Survey Committee set up by the GoI (Government of India), has estimated peak demand for power and energy over the next 15 years at 176 647 MW and 1 058 440 million kWh in the year 2012. We estimate that in order to keep up with the projected growth, an additional capacity of 145 000 MW will be required by 2012. At an average price of US $1 million/MW, this capacity expansion would require about 145 billion dollars in just 15 years, or 9.66 billion dollars every year. This is a monumental task for any developing country, specially for India, where power generation has mostly been the responsibility of central and state governments.

India's energy resources

Coal, oil, gas, and hydroelectric potential constitute the conventional sources for electricity generation in the country. Of these, coal is the primary fuel for power generation because of its large proven reserves in the country. Oil and natural gas reserves are limited and account for a smaller proportion for power generation. The major consumers of natural gas are fertilizer and petrochemical plants where it is used as feedstock. At present, coal and lignite has 53.4% share of commercial energy in the country compared to 16.4% for indigenous petroleum, 17.7% for imported petroleum, 2.7% for hydro, 8.9% for natural gas, and 0.9% for nuclear energy.

The coal reserves are concentrated in the northern and the eastern regions and some parts of central India. Lignite, though in very small quantity, is found in some pockets of southern and western India. Table 3 shows the proven fossil and other fuel reserves. The non-conventional energy potential in India is discussed under the section on renewable energy technologies.

Table 3 India's commercial energy resources

Coal	70 billion tonnes
Crude oil	727 million tonnes
Natural gas	623 billion cubic metres
Hydro (large)	84 000 MW
Uranium	6700 tonnes
Thorium	363 000 tonnes

Constraints in the development of power sector

The power sector in the states is the responsibility of the SEBs (state electricity boards) which generate and distribute power set tariff, and collect revenues. A review of the financial performance of the SEBs indicates that they are incurring very heavy losses as a result of unremunerative tariffs mainly in the agricultural and domestic sectors. Other reasons for their poor financial performance are high commercial losses, substantial arrears receivable, and high distribution losses. There has also been a reduction in the budgetary support from the GoI. As such, it is unlikely that the SEBs will be in a position to invest in new capacity additions. High capital cost associated with high-tech power generation technologies forces India to continue using available conventional technology.

Infrastructure

Although India has substantial coal reserves there has been little investment in the development of new mines. Besides, production in the existing mines has been falling due to various reasons. The gap between supply and demand is widening and the thermal power plants may have to resort to importing coal to meet the shortfall. Transportation of coal supplies is also a major issue because load centres are widely distributed across the country. The Indian Railways plays a crucial part in the transportation of coal to the various thermal power plants. The available infrastructure is highly congested. There are major constraints on long haul coal movement by rail routes to both the west and the east coasts. In the case of coastal movement, ports are also under strain, and report more than 100% capacity utilization. Though there are expansion plans lined up, the development of new facilities will take time due to resource constraints. Even when facilities are available, reliability of service remains a problem. Coastal movement has been increasing consistently over the years with increasing demand from coastal power stations. This affects the choice of fuel for power generation.

Institutional constraints

The IPPs (independent power producers) are faced with considerable difficulties in obtaining the required clearances resulting in delay of capacity addition. However, the major constraint is the signing of the PPA (power purchase agreement) with the utilities. Besides the financial position of the SEBs being pathetic, IPPs find it very difficult to procure the needed finances for the project. It may affect the selection of advanced technologies because of the risks involved and high capital investment.

Coal-based power generating technologies

Coal is India's primary source of energy, accounting for 53.4% of the country's total commercial energy consumption. The high ash content of Indian coal, which results in lower heating value, makes it less competitive with imported coal that has much lower ash content. In India more power is produced by coal than any other fuel. This is likely to remain so for the future. The various coal-based options considered are pulverized coal (sub-critical and super-critical), atmospheric and pressurized fluidized bed combustion, and IGCC (integrated gasification combined cycle) systems.

Pulverized coal boiler (sub-critical and super-critical)

The PC (pulverized coal) fired plant represents the most commonly available technology. In PC combustion, coal is first ground in a mill to a fine powder, along with preheated combustion air. Some of the incombustible matter and unburned carbon is removed at the base of the furnace as bottom ash. The remainder of the ash is carried forward with the hot gases from the furnace. These gases are cooled before an electrostatic precipitator is used to remove residual fly ash. The flue gases are released in the atmosphere via stack. The heat recovered in the boiler and from the hot gases is used to raise HP steam that generates electricity via steam turbine. The efficiency rating of a large utility size power plant is 37% or higher, and that of super-critical steam conditions, multiple reheat, and other refinements can exceed 40% efficiency.

In the case of coal having high sulphur content, FGD is added in order to meet environmental legislation (if it is enforced) relating to SO_x emissions. Currently, there are no SO_x emission standards in India; however, in highly industrialized areas, use of FGD may be required. There are roughly 19 hot spots in India where stringent environmental emission standards have been set by the CPCB (Central Pollution Control Board) and state pollution control boards. There are various methods of post combustion sulphur removal, the wet limestone or gypsum scrubbing being the most common FGD method in use throughout the world. These processes are used for boiler applications with high to low sulphur fuels. In this process, SO_2 containing flue gases reacts with a slurry of limestone in a spray of air and water to produce a hydrated calcium sulphate, gypsum, a valuable by-product. The sub-critical boiler operates at temperature and pressure range of about 540 °C and 165 bar respectively. The super-critical boilers generally operate in the temperature and pressure range of 560–580 °C and 250–265 bar respectively. The operating parameters influence the impacts on the efficiency of the power cycle.

Technological features

- Is suitable for almost any coal mined throughout the world.
- Is economically suitable for a very wide range of boiler capacities.
- Provides wide flexibility in operation and high thermal efficiency.
- Must have proper coal preparation and handling equipment including moisture removal.
- Must have proper means of handling the ash refuse, and must have control on atmospheric emissions arising from elements in the coal and from the combustion process.
- Slow O&M (operation and maintenance) cost as compared to other clean coal technologies.

Commercial availability. It is a well-proven and easily available technology with substantial manufacturing capability the world over. PC technology is available in sizes up to 1000 MW. This technology has also been mastered for inferior quality of Indian coal by the BHEL (Bharat Heavy Electricals Limited). For Indian coal having high ash content the overall size of boiler is large when compared to imported coal where the higher calorific value and low ash content reduces the size of boiler and hence the cost of electricity. Super-critical boilers are not available in India.

Atmospheric fluidized bed combustion

AFBC (atmospheric fluidized bed combustion) technologies are adaptable to both new and existing installations, work well in combination with other technologies, and are suitable for many local coals. In AFBC, the coal, together with some limestone, is crushed and then fed in to the top of the fluidized bed. This bed contains a mixture of unburned coal, ash, and an inert bed material, which is fluidized by injection of air. The temperature in the boiler typically ranges from 820–840 °C. This low temperature is the chief advantage of AFBC because in this temperature range, thermal NO_x is much less likely to form. Furthermore, limestone injected into the furnace captures the sulphur and removes it as a dry by-product. This can greatly remove the SO_x emissions from the plant. During combustion, heat is transferred to a steam cycle via heat exchanger tubes in the fluidized bed itself. This steam is used for power generation in a conventional cycle, just as in the case of pulverized coal system. Two basic design variations are possible, namely, bubbling and circulating AFBC.

Apart from reducing the emissions, the lower combustion temperatures permit the burning of high fouling and slagging fuels at temperatures below their ash fusion temperature. As a result, many of the boiler operating problems associated with Indian coals are greatly reduced. For Indian coal containing high ash, AFBC boiler offers an advantage in fuel preparation over pulverized coal systems. Indian coal requires greater installed pulverizer capacity and the pulverizer requires frequent maintenance. The crushed fuel size for AFBC boilers is 6.5 mm as against -200 mm mesh for pulverized coal boiler. AFBC boilers also offer advantage of fuel flexibility in terms of quality of coal used.

Technological features

- AFBC can remove up to 70%–95% SO_2 – bubbling type AFBC removes SO_2 in the range of 70%–90% while circulating type up to 95%.
- NO_x emissions is in the range of 100-300 PPM (parts per million).
- Boiler and overall plant efficiency are similar to those of PC.
- AFBC technology is suitable for new plants and retrofit applications.
- Suitable for high sulphur coals.

Commercial availability. This technology was first introduced in the 1960s. Since then the development has been concentrated only on small-scale boilers. AFBC technology is commercially available for up to 200 MW.

A number of projects are also planned in the 250 to 350 MW size range. AFBC boilers of 125 MW are operating in Finland and 150 MW in Mexico. Another plant of 250 MW has been in operation since 1995 in France.

In India, BHEL has been carrying out R&D work on fluidized bed since 1975 and has developed circulating type boilers up to capacity rating of 125 MW (390 TPH steam flow) for fuels like high ash coal and lignite.

Pressurized fluidized bed combustion

The PFBC (pressurized fluidized bed combustion) technology uses a combustion process similar to that of AFBC, but the boiler operates at an elevated pressure of 5-20 bar. Heat is removed from the fluidized bed to a steam cycle, as with AFBC. The hot gases resulting from the combustion are at high pressure and after cleaning them, using either cyclones or filters they can be fed into a gas turbine, which can efficiently convert the energy in the hot pressurized gas to electricity. Heat is also recovered from the gas turbine exhaust to the steam cycle. In this technology, limestone is used in the bed to limit the sulphur emissions. This particular technology is also suitable for Indian coal and has all the advantages mentioned in the AFBC technology.

Technological features. PFBC technology has the advantages of AFBC technology (high SO_2 removal, low-NO_x emissions, ability to burn low-quality fuels, and fuel flexibility) and in addition, the potential for achieving plant efficiency (up to 45%) is higher than PC or AFBC (36.5%). It also offers lower capital cost than IGCC or pulverized coal with FGD.

- More than 90% SO_2 removal.
- NO_x emissions at 100-200 PPM.
- Up to 43% efficiency in a combined cycle arrangement.

Commercial availability. At present four PFBC plants are in operation.

- The Varian plant (135 MW and 220 MW of district heating in), Stockholm is now in full commercial operation after having met all availability and performance targets set for the first three years of operation and is owned by Stockholm Energy.
- The Escatron plant owned by utility Empresa Nacional de Electricidad SA, Spain.
- The Tidd plant, Ohio owned by American Electric Power
- The Wakamatsu plant owned by Electric Power Development Company of Japan.
- Another PFBC plant at Karita of about 360 MW capacity in Japan is likely to be commissioned in 1998/99.

Integrated gasification combined cycle power plants

Gasification is a well proven technology which converts a variety of hydrocarbon feedstock like coal, lignite, oil distillates, residues, and natural gas into synthesis gas (syngas). Gasification is the partial combustion of hydrocarbon feed by air or oxygen in ratios that prevent complete combustion but produce synthesis gas. Syngas is essentially a mixture of carbon monoxide and hydrogen. Gasifier temperatures range between 800 °C and 1500 °C. The raw syngas produced is cooled before entering the gas clean up system, such as cyclones and ceramic filter, to remove contaminants. This is followed by gas treatment to reduce SO_x and NO_x to very low levels. This cleaned gas is burned inside the gas turbine combustion chamber, leading to higher efficiency cycles.

There are several different designs of gasifier available, but these basically fall into one of the three categories: fluidized bed, entrained flow, and fixed or moving bed gasifiers. The choice of gasification technology will be determined by technological factors in relation to intended feed and desired products and factors like costs, experience, and track record. Gasification for power generation was stimulated by the energy crisis in the 1970s. The interest is further enhanced by the recognition that gasification meets stringent environmental specifications while converting low value 'dirty' feedstock to electricity with a high efficiency.

The primary constraint to the application of gasification and IGCC plants in India is that the technology needs further demonstration, the costs are higher than those of conventional technologies, and the fact that environmental regulations do not require the high SO_2 removal and low NO_x emissions achievable by IGCC.

Status in India. BEHL has designed and set up an 18 TPD pilot scale pressurized process equipment developed in Hyderabad. This facility has been used for designing 150 TPD pressurized fluidized bed gasifier for setting up a 6 MW electrical output pilot test facility. This is an entrained bed gasifier using 46% ash coal operating around a temperature of 1500 °C. This facility has been in operation since 1990 [Abbi and Ghosh 1996].

A 57.2 MW IGCC plant using lignite as a feedstock is likely to be operational by end of 1998 in the Kuchch region of Gujarat state. This features the U-gas gasification technology developed by the Institute of Gas Technology, Chicago, USA. It is based on air blown gasifier with hot gas clean-up system. HPCL (Hindustan Petroleum Corporation Ltd) is planning to set up a 260 MW, IGCC plant in Bhatinda, Punjab based on petrocoke. The petrocoke will be a by-product from HPCL's new refinery at the same site. India's growing demand for high speed diesel or gas oil (with low sulphur distillates) has led HPCL to adopt a delayed coker technology yielding petrocoke. Although HPCL has not decided on the technology, it has plans to gasify high sulphur content petrocoke to produce syngas and subsequently remove sulphur as H_2S.

Technological features. This technology is in the demonstration phase and is more expensive than other alternatives. IGCC plants can achieve more than 50% efficiency with advanced gas turbines, greater than 99% SO_2 removal, and NO_x below 50 PPM. Entrained IGCC technologies are suitable for low ash coals. High ash coal will require fluidized bed gasification process. Time for construction is expected to be similar to pulverized coal plant with FGD unit. However, phased construction can improve the economics of the IGCC plant by producing power when the gas turbine is installed.

Commercial availability. A 100 MW IGCC plant at the Cool Water site in the US has been in operation for the past five years, during which time its performance with a wide variety of feedstock was validated. Since then a number of design and demonstration projects have come up in the US and Europe. Some of these projects are outlined below.

- A 265 MW plant at Wabash River, using the Destec Two Stage Oxygen Blown entrained flow gasifier with cold gas clean-up
- A 95 MW plant at Pinon Pine using a KRW Fluidized Bed Air Blown Gasifier with hot gas clean-up
- A 55 MW plant at Tom's Creek utilizing a Tampella U-Gas Fluidized Bed Air blown gasifier with fluid bed hot gas clean-up
- A 250 MW plant using the Texaco Oxygen Blown Gasifier with Entrained Air Blown Gasifier with Hot and Cold Gas Clean-up at Tampa Electric
- 253 MW Demkolec plant: potential to be scaled up to 550 MW plant with 51% net efficiency, and installed cost of around US $1500/kW
- A 335 MW Puertollano plant using PRENFLO gasifier in Spain
- A 35 MW EL Dorado plant
- A 42 MW Sterling plant
- A 500 MW ISAB Italian refinery project is scheduled to be operational by November 1999

Pollutants from advanced power generating technologies

The efficiency of coal conversion in Indian power stations is low; the average gross conversion efficiency is about 28%. The present design gross efficiency is about 35%, and enhancing power station performance to increase the operating efficiency to the design efficiency would increase aggregate power output (at the same input rate) by nearly 15%. Pulverized coal electric power generation is the technological choice in the utilities. The principal cause for low efficiency is poor and varying quantities of coal, poor maintenance, and operating practices.

There are many technologies that have the potential to replace PC combustion as the primary coal-to-electricity technology. FBC (fluidized bed combustion) is already commercially available at capacities up to about 200 MW. In addition, there are advanced technologies that show promise. IGCC technology is being tested for techno-economic viability; PFBCC (pressurized fluidized bed combined cycle) is undergoing technological development; and IG-MCFC (integrated gasifier molten carbonate fuel cell) technology is still at the pre-pilot plant stage. The expected efficiencies of these technologies and the estimated emission levels for SPM (suspended particulate matter), SO_2, NO_x, and CO_2 are given in Table 5.

Table 5 Pollution loads of advanced power generating technologies

Technology	Expected* efficiency (%)	Estimated emissions (g/kWh)			
		SPM	SO_2	NO_x	CO_2
PFBCC	38-42	126	0.029	1.42	911
IGCC	40-48	9.5	4.000	0.43	921
IG-MCFC	40-46	6.2	0.096	0.29	778
PC boiler/steam turbine	35-40	205	3.000	9.60	930

* The efficiencies have been updated based on the latest technological developments.

Source. Mathur (1994)

Clean coal technologies add about US $0.01/kWh to the cost of electricity. Higher-efficiency clean coal technologies add 15%-30% to the capital cost of power plants in Asia. However, higher efficiency and lower emissions should prompt low-income Asian countries to develop and adopt lower cost, clean technologies in future.

The extent to which renewable energy sources will become competitive with fossil fuels is an important aspect to be studied. The cost of renewable energy, especially solar energy, with which Asia is richly endowed, has been declining at the rate of three per cent to five per cent a year. If this rate continues, solar energy would become competitive with fossil fuels for some applications between 2010 and 2020, provided governments remove their subsidies on fossil fuels. Small-scale solar energy production is already competitive for rural electrification in remote areas. Biomass, wind, and geothermal energy provision will be competitive with conventional power technologies.

Environmental impacts due to combustion of coal

The environmental impacts of increased coal utilization are primarily the result of the emission of air pollutants arising from combustion processes, coal gasification, or liquefaction plants. These pollutants may be distributed over a relatively large area, whose extent depends upon the design and mode of operation of the combustion or conversion process. Liquid and solid wastes arising from coal utilization generally represent more localized problems.

The pollutants traditionally associated with coal combustion are SO_2 and smoke (particulates). Modern coal combustion systems are designed to avoid the continuous discharge of particulates; in the case of large plants, they are eliminated from flue gases almost entirely by electrostatic precipitation, cyclonic devices, or bag filters. Consequently, increased coal utilization should not result in serious smoke pollution problems. However, the control of SO_2 emissions has proved less feasible in technological or economic terms, making it a potential environmental hazard, particularly in view of the concerns arising from transboundary dispersion. For some time now, attention has been focused on NO_x emitted from coal-fired pore stations is in the form of nitric oxide, which becomes oxidized rapidly in the air to form NO_2. Small amounts of N_2O arise from combustion processes, although most atmospheric N_2O is of natural biological origin. N_2O emissions constitute a potential global problem in view of their possible role in stratospheric ozone depletion and in their contribution to the 'greenhouse effect'. With distance from the source, both SO_2 and NO_2 become increasingly oxidized in the atmosphere. Both dry and wet deposition occur eventually on the earth's surface. Wet deposition, mainly in aerosol form, occurs by in-cloud (rainout) and below-cloud (washout) scavenging. Other emissions of significance from coal utilization include CO_2 and trace metals (including radionuclides).

Fly ash

A major source of solid waste would be from the increasing consumption of coal in the country. It is estimated that on a business-as-usual basis, the total annual consumption of coal would have reached 1384 MT by 2047. With an average ash content of 30% (on the assumption of 100% coal washing at the mines), the total ash generated in 2047 would be 449.8 MT. Of this, 90 MT would be bottom ash and 359.8 MT would be fly ash. Currently in most of the thermal power plants in the country, ash is collected in wet form, which makes utilization of most applications difficult. By 2020, it is assumed that new power plants would have dry fly ash collection facilities. Hence, it would be possible to utilize 100% of the ash. The bottom ash, however, would be in slurry form and would have to be dumped in ash ponds for disposal. By 2047, 8000 ha (hectares) of land would be required for disposal of this bottom ash. The enormous resources that would go into coal transportation in the future would be unsustainable, given the geographical confines of our coal deposits and the high ash content.

Coal gasification would be a technology that provides an answer. Even after 40 years of R&D on coal gasification, India has still not produced a viable technology. The region needs a major breakthrough in this area in the next decade. Another important implication of these estimates is the need for a clear technology development policy. If by 2020 India needs to utilize fly ash collected in dry form, we must have in place the technologies that are commercially viable and functionally acceptable to make this possible. This really means that the R&D policies must clearly target fly ash utilization in an acceptable manner as a clear-cut and time-bound goal to be reached within the next 10 years or so. We will not only be creating a serious environmental problem if this area of priority is not pursued, but also be losing a valuable resource that could provide substantial quantities of building material in a range of applications. As was mentioned earlier, the cement production estimated on a business-as-usual basis in 2047 would be 1303 MT. If fly ash could be used as a building material, the demand for cement would go down to that extent. Improved building techniques and development of superior grades of cement could bring about a further reduction in demand. Consequently, it is possible to foresee that the total demand for cement in 2047 could be limited to almost half of the quantity projected under business-as-usual scenario through plans and policy initiatives that could be adopted almost immediately. This would also halve the severe environmental impacts of the whole cement cycle including lime quarrying, cement production, etc.

Predicting technological progress is almost impossible. Nevertheless, new or emerging technologies are likely to affect the environment in the long run: cleaner and more efficient energy production, pollution abatement, and resource conservation technologies that will lower the costs of controlling pollution, treating waste, and conserving natural resources.

Renewable energy technologies

Renewable energy can play a significant role in de-carbonizing power generation and meeting the industrial and residential heat requirements. Quite a few technologies such as wind, solar thermal, solar PV (photovoltaic), biomass, biogas, etc., are commercially available and are being used in India and other parts of Asia in large numbers. However, there is still a large scope for promoting them. It is expected that at least 40% of the grid-based power generation will be available from renewable energy technologies by the year 2050.

The most important opportunity in the spread of renewable energy technologies lies in creating confidence and conditions whereby private initiatives would come into existence at a decentralized level. A major barrier in this regard is the attitude of electric utilities, which still pursue the conventional approach of favouring large-scale centralized application of power generation and distribution and do not provide a level playing field to non-conventional and decentralized options. There is, of course, a slow acceptance by them of grid-based decentralized power generation through wind farms and cogeneration. However, there is still a dominant resistance to promoting decentralized distribution systems that may function autonomously. The result is that there is an acceleration of technological improvement in grid-based power generation technologies, such as wind machines for producing electricity, but hardly any serious effort in developing wind-pumping systems or biomass gasifiers that could function on a stand-alone basis and benefit large areas where groundwater pumping is a major activity.

While it would not be proper to over-simplify the complexities that characterize the rural energy scene in most developing countries, it has become increasingly clear that small incremental steps will not lead to optimality in the utilization of renewable energy resources. Hence, a major push is needed by which the institutional barriers inhibiting the movement towards optimality can be tackled. A complete overhaul of legislative and institutional arrangements by which energy supply organizations carry on their business today has to start immediately. A serious debate and resolution of the problems in this regard is long overdue, and no further time should be wasted. Table 6 below gives the potential for renewable energy technologies in India as per the Ministry of Non-Conventional Energy Sources.

Table 6 Estimated potential for renewable energy technologies in India

Sources/systems	Potential
Biogas plants (No.)	12 million
Biomass	17 000 MW
Solar energy	20 MW/ km^2
Wind energy	20 000 MW
Small hydro power	10 000 MW
Ocean energy	50 000 MW

Hydro power

The GoI has estimated that small hydro power plants have a potential of 10 GW, although only 220 MW has currently been exploited (predominantly in isolated mountainous regions). Long construction lead times, potential environmental opposition to larger schemes, and relatively high capital costs do not facilitate the penetration of large hydro power schemes, despite promising potential in many areas. The total gross hydro capacity from small and large facilities combined is about 85 GW. Micro hydro plants (up to 3 MW) appear to have a more promising future, with almost 236 MW under construction. However, share of hydro power in total generation has been declining because of the rapid pace of capacity additions and government policies to utilize low-cost coal.

The small hydro programme in India is implemented by at least three government agencies. The mechanisms include subsidies, soft loans, and grants. A main source of current funding is a 70-million-dollar World Bank loan for setting up projects of 15 MW capacity.

Wind

The Ministry of Non-Conventional Energy Sources has stated that the country can become the world's second leading producer of wind energy (after the US) during the next three years. The current installed capacity of wind power generation in India is around 1000 MW and is the fourth largest in the world.

Solar power

The Department of Science and Technology initiated a solar PV programme in 1975. The Central Electronics Ltd, a public sector electronics company, headed a programme of product development while materials and basic research were undertaken by academic institutions and R&D laboratories. The total installed manufacturing capacity of 100 kW was commissioned in 1994.

Unfortunately, the reliability of PV systems has been poor due to the poor design of associated systems components, vandalism, and neglect. Under laboratory conditions, with trained technicians providing regular maintenance, the systems should be almost cost-competitive with grid supplies. Ambones Corporation, in the US, claims to have achieved 20% conversion efficiency for high concentration PV arrays which will lead to capital costs of US $1.50/W of installed capacity or $0.06/kWh for generating electricity. Both examples indicate declining cost potential for PV cells and increasing potential for rural India where diesel generators are the principal means of electrification.

Biomass combustion and gasification

Several options are available to further exploit biomass potential in rural India. For example, the combustion of crop residues like bagasse could be used to produce electricity and heat. Several projects are in the planning stages or under construction of plants in the 150 MW range. Biomass-fired generating plants are proven technologies with substantial operating histories (30 years or more in North America for similar sized plants) to justify additional capacity expansion. However, due to limited availability or cultivation of feedstock, near-term potential is limited, except where large quantities of bagasse, wood chips, or other fuels are readily available. About 64 MT of bagasse and an equivalent amount of wheat straw are available annually, although the collection and transportation costs for such low density fuels have not been calculated. Bagasse is already available in relatively large quantities in sugar mills.

There are plans to include a demonstration programme for the use of fast-growing woody species which could be used as a renewable feedstock. Energy plantations are also being considered for reclamation of saline, alkaline, and waterlogged soils, and in otherwise difficult to cultivate areas, such as steep and hilly ravines. The principal objective of India's programme for energy plantations is to improve rural employment. As of now, about 1800 ha have been brought under cultivation specifically for this purpose. In addition, some combination of woody crops and grasses grown in rotation or in combination with food crops could provide additional biomass for conversion into electricity and gaseous liquid fuels. A grid-connected pilot biomass gasification plant (500 kW) is being set up in Gujarat.

Biomass gasification has been promoted since 1986 to offset diesel use for irrigation, a substitute for electrical pumping of groundwater. Biomass gasification can also produce fuel for diesel-fired generation equipment.

Advanced technologies like BIG or STIG should significantly improve the power output with same quantum of biomass.

The distorted price of diesel pumpsets made it impossible to determine the level of user acceptance of the gasifier technology; in many cases, the gasifier was decoupled from the diesel engine.

Technologies for steel sector

As mentioned earlier, the steel sector is the second largest after the power sector in the consumption of coal. Only 15% of the Indian coal reserves are of coking variety suitable for use in steel making. The consumption of coking coal for steel sector was 33 MT in 1994. The projected demand is 50 and 60 MT in 2001/02 and 2006/07 respectively.

Even the meager deposits of coking coal contain high ash and are difficult to clean. Ash content in the coal supplied to steel plants are of varying quality. The high ash and variation affects the performance and smooth operation of the blast furnace. The ash content in blend for feeding to blast furnace varies from 20% to 22%, to the deterioration of the steel plants designed for consistent quality of mined coal. Every one per cent increase in the ash content results in the increase of coke rate in blast furnace by 23–25 kg/thm. Thus, ash content in coal is very critical for steel sector.

The import of prime coking coals is steadily increasing as the domestic coking coal is deficient in quality and quantity. To reduce the dependence on imports, technologies are required to utilize indigenously available coking coal and also non-coking coal for steel production.

PBCC (partial briquetting of coal charge) enables the usage of a higher proportion of semi coking coal in the coal blend without affecting the coke strength. SAIL is adopting PBCC technology. Stamp charging helps in obtaining better coke strength using inferior coal charge. Tata Iron and Steel Company has adopted this technology utilizing 60%–70% medium coking coal. Selective crushing is another technology in which coal is homogeneously crushed.

Solvent refined coal

Solvent refined coal is a coking agent prepared from non-coking coals/washery middlings as feedstock. Addition of about 8%–10% solvent refined coal in the coking blend has shown significant improvements in coke strength by way of decrease in M10 value apart from reduction in ash content of the coke by

1%–2%. The technology has been developed up to pilot scale of 0.5 TPD by CFRI, India. This coal can replace imported coal but it is yet to be demonstrated with Indian coals.

Formed coke

A number of processes have been developed for the production of formed coke on commercial scale in Germany, Poland, Japan, France, etc., based on non-coking coal and briquetting the char with binder prepared by processing the tar and thereafter curing it. The coke thus produced has been successfully tested in low shaft furnace. The adoption of formed coke in metallurgical application can lead to conservation of coking coals.

Coke dry cooling and non-recovery coke oven

In coke production, wet quenching of hot coke causes atmospheric pollution as it emits about 500 g dust (40% of total dust emission in coke ovens) and 156 g of chemical pollutants per tonne of coke. Coke dry cooling eliminates this pollution, recovers energy from hot coke, and improves coke quality. This results in the reduction of coke rate in the blast furnace up to 3%.

In comparison to by-product recovery ovens, the modern non-recovery type has several advantages in that it is pollution free, flexible, profitable, and does not involve handling of by-products. Two large-scale non-recovery coke oven plants of capacity 0.7 million TPA and 0.24 million TPA are operating in the US and Australia. In India an oven called Kumbhraj has been developed by CFRI.

Coke rate reduction in blast furnace

Metallurgical coal is scarce in India and consumption of coke made from it constitutes the most significant cost factor in the production of hot metal. Energy accounts for nearly 35% of the total cost of steel production and coking coal provides around 80% of energy input. Therefore, efforts are continuously being made to reduce the coke consumption in the blast furnace. The coke rate in the blast furnaces in UK, Germany, and Japan range from 450–525 kg/thm as against 675–750 kg/thm in India. The advanced technologies, relevant to coke/coal in the reduction of coke rate are upgradation of coke quality, and injection of coal dust or coal gas production from non-coking coal into the blast furnace, resulting in the reduction of coke requirement up to 40%. The rate of coal dust injection practised in the advanced countries is in the range of

80-90 kg/thm as against 50-70 kg/thm practised in India. This is a suitable technology for India. The rate of coal dust injection can be increased. The ash content in coal needs to be below 15% which is a detriment in popularizing this technology in India [Rao 1996].

Alternative iron making processes

Blast furnace iron making, the most widespread iron making technology, is capital intensive and dependent on metallurgical coal. These limitations have led to renewed interests in two alternative iron making processes based on non-coking coal, namely, direct reduction and smelting reduction.

Direct reduction includes a large number of processes in which iron ore or pellets are reduced in the solid state by solid or gaseous reducing agents. In these processes, reformed natural gas or non-coking coal is mainly used as the reducing agent and primary source of energy. The final product after reduction is solid and must be melted during steel making with scrap, mostly in an electric arc furnace. The processes used for gas-based reduction are retort, shaft furnaces, and fluid beds; rotary kilns are used for coal-based reduction. Gas-based processes account for 90% of the world's installed capacity because of its advantages over coal-based processes.

Smelting reduction, as the name suggests, involves both reduction and smelting as in a blast furnace where both steps occur in a single reactor. A number of salting reduction processes have been developed which can be classified into three categories: shaft furnace processes, electrical processes, and converter processes. Out of all the smelting reduction processes, COREX is the only one which has reached the commercial stage. A commercial plant of 300000 TPA was started in 1989 in South Africa. A second commercial plant of 600 000 TPA is scheduled to start soon in South Korea. The capital cost of a typical 300 000 TPA COREX plant is estimated at 250 million dollars. A plant of 1.25 million TPA is under construction in India. The following are the main advantages of the COREX process.

- Lower emissions than blast furnace route.
- Wide range of non-coking coals can be used.
- Lower investments and production costs.

The smelting reduction technology has a lot of potential for the production of ferroalloys. The Japanese are working on a process similar to COREX for the manufacture of ferrochrome. This process is less energy intensive compared to the submerged arc process normally employed for making ferrochrome and other ferroalloys.

ROMELT or ferrous liquid phase recovery process is another smelting reduction technology developed using non-coking coal. This was developed by the Moscow Institute of Steel & Alloys, CIS. A semi commercial plant of 300000–350000 tonnes of liquid iron per annum has been set up there. This process is considered unique for the following reasons.

- The process can use iron ore in the size range up to 20 mm including fines without any pre-treatment of beneficiation and agglomeration.
- The process can use run of mine non-coking coal in the size range up to 20 mm.
- Design and operation of the process are simple.
- Cost of production of hot metal is projected to be 10%–30% lower compared to blast furnace.

However, the following drawbacks and technical issues are yet to be addressed.

- The Russian plant used non coking coals of low ash and low volatile matter. Performance with high ash and high VM coals such as those available in India have not been demonstrated.
- The process is oxygen intensive around 700 NM^3/thm.
- The waste gases from the furnace carry away 25%–30% of the energy input upsetting the economics of the process.

Mini blast furnace

The large blast furnaces are associated with high investment, large capacity for economy of production, stringent quality of raw materials, etc., while the mini blast furnace is characterized with lower investments, smaller capacities, lower gestation periods, and market-oriented locations.

A large number of mini blast furnaces are operating in Brazil, China, and India. Operation of the mini blast furnaces with charcoal and coke has been extensively tested. China uses metallurgical coke and the coke rate varies between 550 to 630 kg/thm. Injection of pulverized anthracite coal to the extent of 60 kg/thm has been tried which has brought down the coke rate by about 40–50 kg/thm. A mini blast furnace of 175 m^3 capacity at a capital cost of 10.72 million dollars was commissioned in Goa (India) in 1992. The coke rate of the plant is 600 kg/thm.

Direct steel making process

Conventionally steel making from iron ore is a two stage process - iron making and then steel making. Attempts are being made to develop a process wherein steel could be produced out of iron ore or coal without converting them to pig iron as in the case of blast furnace. Such a process has been classified as direct steel making. The RESINESS process is one such process. The name RESINESS combines three metallurgical operations, RE for reduction, SIN for sintering, and ESS for electroslag smelting. This process uses iron ore fines and non-coking coal which are preheated to 300–350 °C. The preheated mixture is charged continuously in an externally heated retort maintained at 1000–1020 °C to simultaneously reduce the iron ore particles and sinter the reduced iron which is then electroslag smelted to directly produce steel. This technology is at the laboratory stage of development.

Tools for industrial transformation

Apart from the power sector the other coal intensive industries are the iron and steel, cement industry, and the pulp and paper industries. By 2047, the iron and steel industry would produce approximately 8 MT of suspended particulate matter; the cement industry, about 13 MT; and the paper and paperboard industry, below 1 MT. While industrial location would become an important factor in reducing the harmful effects of pollution from industrial sources, for certain industries the development and widespread use of specific technologies would acquire increasing importance. The answer would also lie in promoting a mix of industries that have relatively low harmful impacts on the environment. In other words, the current trend of dirty industries migrating from the countries of the developed world to those of the developing world cannot possibly continue for a country like India. Much greater efforts will have to be made towards achieving a relatively high growth of the services sector so that a larger share of economic output in the country would be provided by services rather than manufacturing. This would require India to adopt a strategic direction because restructuring of the industrial sector is a fairly long-term process. For instance, it has taken Japan a quarter century to alter its industrial structure towards a low energy intensive mix, even though the country did show dramatic results in the first few years after the oil price shock of 1973/74.

Environmental decision-making has to be merged with the mainstream economic decision-making. Environmental costs, therefore, would need to be internalized effectively, but these costs cannot be estimated uniformly because the severity of environmental impacts varies substantially from location to location, both in physical and economic terms. In most of the countries where environmental standards have been effectively set and enforced, local conditions have been paramount in providing a rationale for such standards. In essence, what India and other countries in the region have to seek is the lowest possible environmental Kuznets curve. If appropriate cultural institutional, technological, and political conditions exist, then countries like India can move along the lowest possible curve, distinct from the record of the developed countries.

Environmental indicators

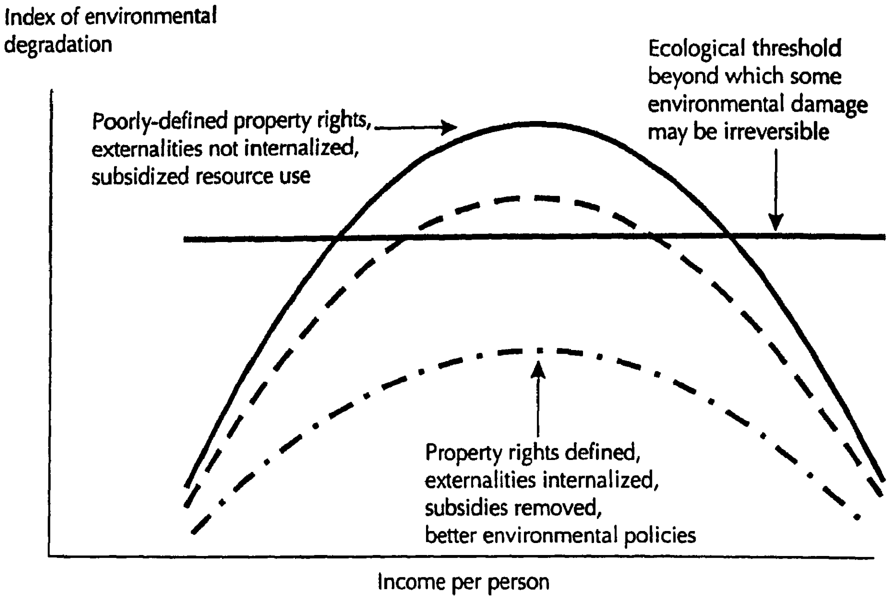
Development of environmental (air, water, land, social) indicators for evaluation of performances in mines, power generation, and steel production may be considered.

Environmental Kuznets curves

During the process of industrialization, materials and energy consumption and emissions and ambient air concentrations may follow an inverted-U curve with respect to income (first rising levels of substance flows per unit of income, later in absolute terms). When applied to pollution, this has been called the environmental Kuznets curve (Figure 4). Evidence of such patterns has been found on a case study basis for several materials and pollutants and energy, but almost solely for developed economies. The reasons given for such patterns are quite diverse, and different research groups emphasize different elements. More efforts may be undertaken to fully understand the driving forces behind the observed inverted-u curve.

Studies on Asia throw light on this in a different way. Much of Asia's environmental degradation took place and accelerated during the region's rapid economic growth of the past 30 years, and during the next 20 to 30 years environmental quality will improve slowly in East Asia and in the higher income countries of South-East Asia and will continue to deteriorate in South Asia and the lower-income countries of South-East Asia.

Figure 4. Keeping within the threshold of environmental damage



Also, for certain pollutants, such as SO_2, heavy particles, and faecal coliform in rivers, there appears to be important differences in the income-environment relationship between Asia and the rest of the world. In Asia certain types of pollution tend to rise more rapidly with higher income than they do elsewhere, but they also begin to fall more quickly. Higher initial population density together with more rapid industrialization may account for the rapid rise, while increased environmental awareness and the availability of new abatement technology permit pollution to be reduced at relatively lower income levels.

However, certain questions need to be explored. Are these observed relationships between income and the environment inevitable? Must a worsening environment always accompany economic growth or can the environmental Kuznets curve be flattened?

Key elements of the future waste management infrastructure involve industry, government, and the consumer. Within the firm, consumable products should be designed for safe dissipative use, and service products should be designed for easy disassembling and recycling. Governments should re-align responsibilities, encouraging leasing and other mechanisms to ensure that producers have incentives to design products for lower life-cycle environmental impacts.

Enlightened governance and policy-making

This requires a shift in the very concept of governance, which is not fully realized by the current political system or officialdom in India. Given the enormous variation in local conditions in different parts of the country, environmental standards and norms have to be set specific to each location, and therefore, they must have the full participation of the local people. Action to implement long-term solutions would, therefore, also require partnership with and participation of local people and institutions.

Materials flow and balance analysis

Materials flow studies reveal structure and webs of economic and material relationships among actors in the industrial system as they map the flow of natural resources into processing and manufacturing industries and the fate of products and wastes existing in them. The object for study can be the mass of individual chemical elements, compounds, or entire classes of materials. The framework of such studies include individual facilities, whole industrial sectors, and geographic regions.

The sectors identified for more comprehensive studies are coal, iron and steel, and cement. However, this should not be considered as a final list as it has been selected based on major coal consuming sectors. Consideration of these sectors begins with the amount the nation consumes, goes on to how much escapes from processing, and ends with the consumer and finally in nature as scrap or other toxic elements.

Industrial ecology

A crucial goal of industrial ecology is to develop and sustain the dynamics of technological improvement. Progress is being made in planning, designing, and implementing industrial ecology systems where the goal is to close the loop to achieve near-zero waste. In the production of consumer products, engineers apply a systems approach as they optimize individual processes and integrate subsystems with megasystems. The recognition that participation in this process makes good business sense is a motivating factor.

Several different strategies for companies focusing on environmental aspects have been defined. They form the basis of research that can be labelled 'industrial ecology'. Most of the research conducted under the heading of eco-efficiency is applied and relatively technical. When this research is more closely connected to the social sciences and policy analysis three problems arise.

The first is related to the question as to why profitable pollution prevention opportunities continue to exist in many companies, often for decades. Similarly in the area of energy conservation, substantial opportunities to reduce energy consumption exists but there is a big energy-efficiency gap. The efficiency gap has been explained in terms of high information costs, sensitivity to high investment costs and liquidity constraints, bounded rationality, and principal-agent problems.

The second related problem is that the design of an effective environmental policy crucially depends on a better understanding of when and to what degree companies will implement eco-efficiency. Research is needed in factors that make industry move, i.e., in the incentive structures. Eco-efficiency is probably not driven by cost-reduction opportunities, but by the conscious effort of company management to improve the environmental image and avoid regulatory burdens and future liability. Policy options for the promotion of eco-efficiency range from providing information to instituting eco-taxes.

The third problem is related to the overall environmental success that pollution prevention and related strategies can provide. Pollution prevention advocates have traditionally focused on success stories. These case studies help to stimulate the interest of industry, but they do not provide policy makers with insight into the potential role of each eco-efficiency strategy in environmental policy. Also, a better understanding of how and how much eco-efficiency can reduce pollution is needed to develop policies that can support the implementation of the strategies. The assessment of the effectiveness of eco-efficiency requires two elements, a model and understanding of firm decision-making and the ability to assess and compare the overall pollution of industry.

The sectors discussed here are closely interwoven - coal, power, steel, and other industrial sectors like cement. The wastes generated from the power plants and the steel plants can be effectively utilized in various industries.

Future mining technologies

In the excavation and transportation front, importance should be given to the introduction of inpit crushing and conveying system, surface minor for selective mining, high capacity dragline to cater to higher stripping ratio, electric wheel, and high capacity truck haulage system. For drilling, electric discharge should be adopted where compressed electric energy is discharged at very high voltage from electrodes for breaking rocks. Pit surveying should be conducted using the techniques of global positioning system and automated field instruments. Cross pit and around the pit conveying system, along with continuous spreading operation interfaced with excavators, is required for proper dump management. Central despatch database, a maintenance management system, is interfaced through a common protocol to provide on-line expert system for continuous control maintenance of machine health. Importance should be given to the introduction of information technology for complete networking of activities. Radio transmission and computer interface compatibility throughout the mine by total mine system integration.

Methane extraction from *in situ* coal-bed

It is recognized that methane can be produced from virgin coal seams independent of the coal mining operation. Methane remains in the coal seam in one of the three possible ways, namely, adsorbed form on the internal surface of coal matrix, as free gas within pores and fractures, and as dissolved gas in formation waters. The co-occupance of methane in coal depends on coal rank, type of organic matter, temperature, and time of burial. It is established that the greatest amount of methane in a particular rank of coal is generated in the medium volatile and low bituminous ranges. Coal seams having vitrinite reflectance range of 0.7%–1.7% and available between the depth range of 300–1200 m are most suitable for commercial production of coal-bed methane. The reserve of such type of coals in India are about 29 BT and are mostly located in the coalfields of Damodar-Koel valley. Coal-bed methane resources are estimated at 850 billion cubic metres.

Various economic and legal issues related to coal-bed methane need to be addressed before entering into large-scale production of coal-bed methane in India. Some major issues are economic viability, tax incentives, legal issues, and marketing. Coal is a separate mineral resource and at the same time a source of methane gas. It needs to be sorted out whether the rights for coal and gas should be separately held and necessary legislation needs to be passed.

Since coal-bed methane exploration and exploitation are very costly processes, one needs to work out the economic viability and introduce some kind of financial incentives to attract the companies into the venture. Market availability needs to be established and ensured before going for any investment.

Dematerialization

Materials substitution is considered a principal factor in the theory of dematerialization. The theory asserts that as a nation becomes more affluent the mass of materials required to satisfy new or growing economic functions diminishes over time. The complementary concept of decarbonization, or the diminishing mass of carbon released per unit of energy production over time, is both more readily examined and has been amply demonstrated by researchers over the past two decades. For materials in general, several forms of innovation (more efficient recovery of minerals and metals from crude ores, imbuing materials with improved properties per unit mass, and better societal mechanisms for handling and reusing wastes) drive this phenomenon.

Pollution prevention

Pollution prevention focuses on process optimization, input substitution, and better housekeeping measures. Some of the important source reduction practices are (1) equipment modernization and modification, (2) improved maintenance, (3) improved operation practices, (4) inventory control, (5) process and/or product modification, (6) substitution of inputs, and (7) in-process recycling.

The issues of discussion are how feasible are these measures and the potential and implementation strategies for reducing the emissions from industries. The environmental management systems adopted by the industries / corporate houses play a major role in this direction.

Life cycle analysis

Life cycle analysis has been defined as a way to 'evaluate the environmental effects associated with any given industrial activity from the initial gathering of raw materials from the earth until the point at which all residuals are returned to the earth'.

It is an important tool for eco-efficiency. The aim of LCA is to provide information about environmental impacts in production, use, and disposal of different products. The development of LCA was prompted by the desire to avoid shifting pollution to different life cycle stages to minimize pollution at the specific stage.

The question is how to accomplish the tasks of transferring pollution from one stage to another, and how to ensure proper control at source or safe handling of waste/pollution to minimize the adverse affects. It becomes very important in the context of greater dependence on coal because of its associated pollution problems and the limitations posed by the technologies in minimizing the emissions into atmosphere.

Environmental management systems

Corporate ecological control can be an effective tool for environmental management. The first step in corporate ecological control is to identify and analyse all current activities in production and develop an ecological balance. In an ecological balance, the inputs of raw and processed materials are compared quantitatively with the resulting products and emissions, including waste materials, waste water, fumes, waste heat, and noise. To make the data useful for company decision-making, it must be systematically processed and assessed for relevance to environmental issues. The result is a 'weakness analysis', which forms the basis for formulating ecologically oriented company objectives and establishing concrete remedial measures. Weakness analysis is designed to help a company identify and assess alternative products, technologies, processing materials, and production methods.

An essential part of corporate ecological control, which is an ongoing process, is the constant scrutiny of measures adopted earlier. Advances in ecological research may reveal that well-intended modification or substitutions have larger environmental effects than were earlier understood.

A proper ecological balance will identify and assess as many environmental effects as possible relating to industrial activities.

Institutional aspects

Major economic reforms were initiated by the GoI in 1991 with emphasis on privatization and removal of bureaucratic hurdles like licensing and determination of capacities. Significant reforms were also carried out in the financial sector to allow direct foreign investment.

Reforms in the coal sector

The Coal Mines Nationalisation Act, 1973 was amended in the year 1993 to allow for captive mining in the power and steel sectors by the private sector. The amendment also permits the setting up of washeries for coal washing by the private sector. Further amendment took place in 1996 to allow captive mining in the cement sector. About 71 coal blocks have been identified for captive mining estimated to have a reserve of 20 000 MT. The captive mining experiment has not been successful for various reasons. Some of the important ones are indicated here below.

- Captives mines are debarred from selling the coal to other consumers.
- The captive mine owners had to depend on railways for shipment of coal to the plants for consumption.
- Land acquisition was costly and time consuming.
- The size of many of the coal blocks allocated was not economical for profitable mining.

Further amendments are being considered to remove the barriers indicated above. The government is also planning to set up a regulatory body to perform the appellate function resolving price disputes between producers and consumers.

The government has made significant investments in the welfare of the mining workers. Approximately 100–150 billion rupees has been invested in providing welfare facilities like housing, medical, and security. Significant skill upgradation has taken place among the workers in the opencast mines. However, the skill levels in underground mines remain pathetically low. The welfare programmes has brought about a marked reduction in the accident rates and has improved the living standards of the workers.

Reforms in the power sector

Electricity is the costliest form of energy. At the point of delivery to the consumer, the ratio between the amount of energy delivered and the fuel energy required to produce it is around 25%–30%. The main objective of the energy supply side is to develop power generation technologies that raise the efficiency of existing power generation plants. Upgrading transmission and distribution facilities can also result in significant energy savings. Better metering systems, modern billing techniques, and more stringent collection of electricity charges would also improve matters. Price is a major determinant of electricity demand and end-use efficiency. However, the contention of policy makers that prices below true opportunity costs lead to wasteful electricity consumption is inadequate.

In recent years, many governments in both industrial and developing countries have introduced reforms in their power sectors. Most East Asian countries have invited the private sector to invest in power projects. Participation by IPPs is only an intermediate step, however. Power utilities themselves should shift to private hands. The privatization of electricity generation should be a critical goal for all Asian governments, but its success depends on effective regulation. The process must be transparent, enabling interested parties and the public to identify the basis for the regulator's decision. Effective regulation must also be insulated from political influence to prevent special interests from influencing government decisions. Such steps, together with maintaining a stable political climate, are essential if private financing of energy investments is to be maximized.

Privatization must be accompanied by the most important reform in the energy sector, the removal of subsidies, both explicit and implicit. Policy makers should supplement the removal of energy price distortions by introducing fiscal policy reforms that encourage investment in renewable forms of energy.

Conclusion

The Asian economies are poised for a high growth rate and with the current population well in excess of three billion, the production and utilization of energy will remain one of the major development challenges for Asia, with coal playing a major role for years to come. The region has undergone enormous changes over the past decade in terms of growth and consumption patterns including a sharply increased reliance upon various sources of energy. While this increased use of energy has undoubtedly improved the standard of living for many people in the region, it has also left its mark on the environment. This paper has tried to identify a research agenda based on major thrust areas and the threat to the environment.

The increased awareness of the Asian countries of the potentially negative consequences of current patterns of energy use has prompted a reassessment of the country energy strategies which are currently in force. It has become clear that the issue of energy production and utilization can no longer be considered in isolation from the broader concerns of sustainable human development. As a result, there is a need for a more thorough analysis of the trade-offs between the supply of energy at affordable prices and overall environmental quality. The well-being of current as well as future generations will need to be factored into energy strategies and policies.

References

Abbi Y P and Ghosh A K. 1996.
Clean Coal Technologies for Power Generation.
In Proceedings of Asia Energy Vision 2020: Sustainable Energy Supply.
Organized by the World Energy Council and the Institution of Engineers, India, 15–17 November 1996, New Delhi, India.
New Delhi: Institution of Engineers, India.

Chadwick M J, Highton N H, and Lindman N. 1987.
Environmental Impacts of Coal Mining and Utilization.
Pergamon Press.

Mathur A. 1994.
Potential for introducing advanced technologies for power generation in India, pp. 167–184.
In Proceedings of the Training Workshop on Environmental Issues Related to Electric Power Generation Projects in India, 4–6 March 1993, Jaipur, India.
Manila: Asian Development Bank.

Pachauri R K.
Looking back to think ahead, GREEN India 2047.
New Delhi: Tata Energy Research Institute (In press).

Rao O P. 1996.
Technologies for utilisation of high ash coals - Indian perspective, pp. 75–85.
In Proceedings of Asia Energy Vision 2020: Sustainable Energy Supply.
Organized by the World Energy Council and the Institution of Engineers, India, 15–17 November 1996, New Delhi, India. New Delhi: Institution of Engineers, India.

Macroeconomic issues related to IHDP-IT

Shreekant Gupta, Delhi School of Economics

To my mind global environmental change, particularly climate change, is an unprecedented challenge facing us today. Given that we human beings have brought this challenge upon ourselves, i.e., given the anthropocentric nature of climate change, I think the IHDP (International Human Dimensions Programme) is a very important and vital initiative. Within this overall framework, industrial transformation is perhaps the most significant component simply because industrial activities have been the primary contributors to global environmental change. The industrial transformation that we have witnessed over the last two and a half centuries has been unprecedented in the human experience. While this change has brought tremendous prosperity in many economies and still holds promise for many other poor countries, it has not been an unmixed blessing. It has been accompanied by problems that were not anticipated, certainly not by economists. In fact, these problems have often threatened the very sustainability of the process of industrial transformation. It is, therefore, very appropriate and commendable that the IHDP–IT initiative attempts to 'understand the human drivers and mechanisms that could enable a transformation of industrial systems towards sustainability' and at the same time tries to mitigate the environmental impacts of industrial activities. To put it differently, there is a sort of a two-way interaction between the economy and the environment, and this realization has come only belatedly to the economists. For example, we now realize that environmental degradation hinders economic growth including industrial growth and at the same time lack of economic growth hurts the environment. Dr Pachauri very presciently mentioned that poverty is the worst polluter. The primary focus of what I am going to talk about is the second direction of the costs, i.e., the effects of economic growth, particularly industrial growth, on the environment, and how to make these more environmentally benign.

Let us very briefly touch upon the ways in which environmental degradation of air and water pollution can affect industrial growth. By reducing the quality of life and by imposing health costs, pollution can offset some of the gains of rising incomes. Pollution can also reduce the productivity of resources such as air and water, thereby affecting industrial growth, which of course is quite well-known and is worth mentioning.

Coming back to the effect of industrial transformation on the environment, I could put forward at least four reasons why lack of economic growth could hurt the environment. It has already been seen how the environment can affect the economy and how the economy can affect the environment. As was mentioned earlier, poverty is the worst polluter. Also evidence does show that as incomes increase so does environmental quality, and I would add the rider, eventually. I would agree that in the long run there is a strong positive correlation between economic growth, income growth, and environmental quality. Secondly, it is also being shown that poor people have much higher discount rates for the future, i.e., they care much more about survival today than what happens tomorrow. Thirdly, in economics we would say that environmental quality is what is called a normal good. That is, demand for environmental quality, willingness to pay for environmental quality, increases with income. And finally sound economic policies lead to growth, for example, elimination of subsidies on fossil fuels, making state-owned enterprises more competitive, and so on. Thus, good economic policies are also good for the environment. And these are what have often been called the win-win opportunities. The challenge then is not to forsake industrial transformation, which I view as the engine of economic growth but to make such growth environmentally sustainable.

I would like to elaborate on macroeconomic incentives in the context of what I would call policy failures and market failures, how these affect the environment, and how we can weave all these into sustainable industrial transformation. Fortunately, we economists like to think that we have a fairly comprehensive view of this problem. While industrial growth is good for the environment, industrial transformation can also give rise to environmental problems for the two reasons already mentioned – policy failures and market failures. I want to discuss these briefly before linking them up with macroeconomic incentives for industrial transformation. Policy failures are, and have often been called, government failures, i.e., distortions in goods and factor markets like quotas and subsidies, removal of which would lead to both economic and environmental gains. These are the win-win policies. Policies which improve the efficiency of industrial or energy-related activities can reduce both economic waste and environmental pollution. Market failures, on the other hand, are slightly different. These would be defined as unintended adverse environmental effects of economic activities. For example, if you take air pollution caused by a factory, which in the course of legitimate economic activity affects the health of residents near the factory, these effects would be called negative environmental externalities or unintended negative effects of production and consumption by economic agents on other producers and consumers both within and outside the country. In other words, market failures arise when there are externalities. These kinds of environmental effects are generally a by-product of economic activity and are usually unintentional. Pollution is not a malicious act of trying to cause deliberate damage. Typically, the costs are borne by others and not by the generator of the externality. Market failures can arise even in the absence of policy failures. So even if you have eliminated all other kinds of policy distortions, you could still have environmental problems arising from environmental externalities. So broadly, one could think of the kinds of environmental problems that arise in industrial transformation as stemming from these two broad categories. The fact that market failures can arise even in the absence of policy failures is worth emphasizing. While I did mention a large class of win-win policies that are good both for the economy and the environment, at the end of the day, once all policy failures have been addressed, one still needs to address the remaining problems of market failure. It is evident then that the whole issue of macroeconomic incentives for industrial transformation is one of addressing these policy and market failures. In other words, for sustainable industrial development it is important to get the incentives right. I would like to emphasize that it is very important to get the incentive structures right, to internalize the externalities, and then let the markets do the rest. Beginning with policy failures, as mentioned earlier, good economic policies are generally good for the environment while links between economy-wide policies and the removal of price distortions, promotion of market incentives, and relaxation of other constraints generally contribute both to economic and environmental gains. I would like to illustrate this point by looking specifically at the energy sector. Numerous environmental problems are associated with energy consumption, like emissions of greenhouse gases, SO_x, NO_x, SPM, and so on. But in my view while energy conservation has a lot of potential, it is not a panacea. Even under an energy-efficient scenario, economic development will require substantial increases in fossil fuel consumption for the foreseeable future. In fact, based on this very useful background note that has been prepared by TERI for this workshop, it has been estimated that additional power capacity of 145 000 MW will be required over the next 15 years in this country. And much of this increase will have to be met through fossil fuel based power generation. Electricity generation is assumed to increase well over five per cent a year. And further, as in the case of India, coal combustion is currently the main source of electricity production and accounts for 80% of Asia's coal consumption. As the TERI background paper states, coal use will continue to rise in Asia due to its abundant availability and cost advantage. In this context, policy failures, particularly pricing reforms, have to be examined. Substantial progress in reducing energy intensity and controlling the level of pollution per unit of energy generated can be achieved by combining the potential of technical interventions with price reforms. Ideally, we would like prices to be equal to both short- and long-range marginal costs (SRMC and LRMCs). There have been several studies on energy pricing, and it has been inevitably found that prices are below LRMCs. Surveys have also shown that tariffs in developing countries have actually decreased. Prices are less than half of those prevailing in OECD (Organization for Economic Cooperation and Development) countries even though average costs in developing countries were higher. Average tariffs which were nearly 80% of the utilities, did not even cover LRMCs, and so on. The bottom line is that such low prices require enormous subsidies that represent major drains on government budgets. For example, the World Development Report, of the World Bank in 1992, noted that energy subsidies exceeded about 150 billion dollars annually in developing countries. For electricity consumption alone subsidies amounted to over 100 billion dollars per year. If LRMC pricing was used, energy savings would result to the tune of nine billion dollars per year in China and about four billion dollars in India. To sum up, energy price reform would fall well into this win-win category. For example, the benefits from increased electricity tariffs will be two-fold (1) efficiency gains, where reduction in consumption due to higher prices may result in savings in capital and operating costs, and (2) reduction in emissions of various kinds. Thus, if you are thinking about macroeconomic incentives for industrial transformation, it is important to get the incentives structure right. To illustrate from the example of energy, it is important to get the prices right. Unless one does not get the prices right, lots of the technical solutions are not going to deliver the goods. This is the message that a lot of the economists would provide.

Market failures pose the second kind of problem, i.e., even if policy distortions were being corrected, one would still have environmental externalities, which will have to be addressed. Again economists have long advocated the use of economic instruments to address these types of environmental problems. These instruments range from pollution taxes and tradable permits to input taxes and differential tax rates. The common element amongst all these is that they work through the market and alter the behaviour of economic agents by changing the nature of incentives and disincentives these agents face. We also, therefore, call them market-based instruments. The basic philosophy behind this approach is that environmental problems related to market failure occur either due to the absence of well-defined property rights or due to externalities, which have not been internalized. For example, if tradable permits are created or if polluting firms are confronted with the true social costs of the activities, then these environmental problems can be mitigated. The point is that economists view environmental problems associated with industrial growth in terms of either getting the incentives structure right or in eliminating policy failures and internalizing the externalities. The market should take care of the rest.

The research agenda for industrial transformation should flow from this built-in agenda. The reason why environment friendly technologies, say solar water heaters, have not been widely used or the so-called technical research has not got on, is because changes have to be made in the nature of incentives and disincentives. We simply cannot appeal to the good conscience of people to have sustainable industrial transformation. There should be incentives to buy a product.

Consumption of energy and materials in South Asia

Leena Srivastava, TERI

Exhibit 1 Poverty and inequality indicators

	Poverty rate (%)	Income ratio
Bangladesh	45.0	4.1
Bhutan	n.a	n.a
India	29.9	4.7
Maldives	40.0	n.a
Nepal	42.6	4.3
Pakistan	n.a	4.7
Sri Lanka	39.4	4.4

Exhibit 2 Water and sanitation

	Water (%)		Sanitation	
	Urban	Rural	Urban	Rural
Bangladesh	82	85	63	26
Bhutan	60	30	50	7
India	85	78	62	12
Maldives	n.a	n.a	n.a	n.a
Nepal	67	39	52	3
Pakistan	85	50	60	17
Sri Lanka	n.a	n.a	n.a	n.a

Exhibit 3 What does this mean?

- Economic growth paramount
- Services demand will increase
- Energy consumption will increase

Exhibit 4 What is also true?

- Huge inefficiencies in the systems
- Enormous waste generation
- Poor quality and reliability of infrastructure

Exhibit 5 Causes and consumption implications

Causes	Consumption impacts
• Inadequate public transport	• Higher energy consumption
• Poor roads	• Frequent laying of roads
• Low speeds	• Vehicle wear and tear
	• High inefficiencies

Exhibit 6 Road surfaces

Bituminous roads	Cement roads
• Require strengthening every 5 years and maintenance almost every six months	• Life of 50 years with minimal damage
	• Almost three times the cost
• Bitumen consumption 0.2% by weight of road section	• 20% by weight

Panel discussions

- International issues related to IHDP-IT
- Issues in industrial transformation in South Asia

International issues related to IHDP-IT

Robert H Socolow (Princeton University, USA)
I wish to request the two panellists to make comments on what they heard in the morning and how they want to relate it to the nation's interest. Then I will step down and we will go into the second afternoon session which would feature a greater amount of discussion from the group than we have been able to have before, as well as the panel of three people, chaired by Pier Vellinga. I would like now first to ask Dr Katsuo Seiki to make some comments.

Katsuo Seiki (Global Industrial & Social Program Research Institute, Japan)
There are so many international studies entitled 'sustainability' or 'sustainable development'. It is very meaningful at this stage to compare notes among those study teams, assess the state of the art, identify the missing points, and promote the interface among people. The last seems to me particularly important as there is no effective interface between economists, engineers, and social psychologists. I am currently trying to organize a joint US–Japan study group on climate change policy and macroeconomic policy.

We would like to see more macroeconomists who are willing to talk about climate change policies. The case of our country may be exceptional, but not unique. In many countries, especially in Asia, dialogue between experts in different disciplines is totally missing. If this initiative could bring about such opportunities or forums for experts of various disciplines to hold a discussion, it would be very significant. In addition to that, this initiative should identify the missing points of the discussions so far made also called 'sustainability or sustainable development'. Let me put forward examples of this. The first is about the macroeconomic dimension of sustainable development policies. Everyone who considers only the future dematerialization or decarbonization talks about the possible picture which would be achieved after such an initiative would be implemented. We may lose a lot of 'value-addedness' if we promote factor ten. The same thing will apply to the IPCC assessment of 60% reduction or 50% reduction of carbons which can be achieved by the reduction of energy use to 50%. How would it affect the macroeconomic picture or industrial structure picture? That question is yet to be answered.

Prof. Socolow, who is working on the same research, says that the future economy or industrial structure would have an extremely low growth rate, and it may not ensure full employment. This is the first missing point.

The second missing point surfaced from the discussion by Dr Gupta. I fully agree with all the original economic analyses that we must eliminate all subsidies and eventually eliminate all market failures by using economic instruments like taxation. But consider the speed and magnitude of the transformations we have to carry out, for example, in the context of climate change policy. Let us say our country has to reduce six per cent CO_2 or greenhouse gas by the year 2010, below the level of 1990. If we are to reduce our CO_2 emissions to zero, that is the 1990 level, the macroeconomic indicator called energy–income elasticity would show a ratio of 0.1, if an annual economic growth of two per cent is assumed. For the last five to ten years we have been experiencing 0.7 energy–income elasticity ratio. During the period of oil crisis, when the oil prices shot up four times, we experienced an energy–income elasticity ratio of 2.4. So if oil price will rise four times, then we might be able to achieve it. But without that we will have to find a totally different way to achieve even this zero per cent target, which calls for an entirely different set of policy frameworks. The solution economists would give is to raise taxes. This will kill our macroeconomy. We have to dwell on the sort of economic instruments and policy measures we have. This is an important area of study where economic instruments and policy measures have to be sharpened to bring about a zero per cent reduction.

The third missing point is technology developments. The concept of industrial ecology had at least methodologically been launched by Prof. Kaya in Japan in 1968. Thirty years have passed since, but policy makers have not paid it much attention. The concept of industrial ecology, zero emission, or eco-efficiency has attracted the attention of neither business leaders nor government leaders. The evidence is the declining R&D expenditure by both the public sector and the private sector. Policy makers talk about technology development in generic terms. They need to be told that the speed of technological innovation is in such a shape that within five years we must have a new technologies to reduce our CO_2 emissions by five per cent. Such a concrete indication may be necessary for policy makers to be serious enough to consider those new concepts. I think all this 'sustainability' discussion is totally lacking in the discussion of a practical adjustment of the speed of sustainability. They say that markets will tell whether the price is high enough for your technology to come in. It is said that enormous technological innovation has to take place in order to achieve sustainability. Keeping this in view, I feel that the management of transition or adjustment of speed for sustainability is totally lacking. Therefore, it can never be practical.

Management of transition is another missing area in our discussion on technology development. It was mentioned that the market mechanism is an unavoidable foundation for any policy measures. The value system of the consumers will have to be totally changed when factor ten would be realized. It has to be based on so-called dematerialism, on community sense, which is missing in the market place. Market is competition – be rich, just get everything which is materially important. The participation of social psychologists in the full analysis of consumer behaviour may be necessary.

The last one point is on the confusion in our discussion on sustainability is the time perspective. We do not know in what time perspective one discusses. Depending upon the time frames you take, the discussions may vary. That confuses the sort of discussions we are having in sustainability.

Kulthorn Silapabanieng (Chulalongkorn University, Thailand)
The term 'industrial transformation' could be considered as an entirely new terminology in Thailand. However, I realize that industrial transformation is going to be the most important element if one tries to reach the goal of sustainable development by the industry. With this in mind, and with my background as an engineer, I endorse my support under the category of industrial ecology and eco-efficiency, particularly those relating to prevention of pollution, clean technology, and material setting, in that order. Also, it is obvious that industrial transformation is an inter-disciplinary research programme encompassing science, technology, natural sciences, social sciences, etc. You name it, and it falls into the industrial transformation category. Therefore, there is a need to narrow down the field of research in order to be very specific and reach the ultimate goal in the right direction in the shortest period of time. I foresee the need for a country like Thailand to benefit most from industrial transformation research work. Good results can be applied or put into use within a short period of time. In the case of Thailand, there is a need of research in the area of energy and environment. This is a clear application of industrial transformation to a country in need of protection with new and cleaner technology that will not degrade the environment. For example, the power sector in Thailand generates electricity by means of conventional pulverized coal in the thermal power plant. This has created plenty of environmental problems during the past 10 years due to high sulphur ash content. The power sector must look into a cleaner technology to produce electricity. Here, a new clean coal technology such as coal gasification power plants should be seriously looked into. Gasifiers remove dusts and other undesirable impurities in the gas treatment process, leaving only clean gas to be

burned in a combined cycle power plant. This is just a typical sample where industrial transformation research work would be of use to a country in need for better protection technology.

S P Ghosh (National Council for Cement and Building Materials, India)
I wish to remark on the point made by the last panellist on clean coal, the gasification of coal. Although this technology has been well-known in Europe and the US for a long time, in developing countries as we see today, this technology could not make any entry because of the many social, socio-economic, and employment generation problems faced by them. Our experience with both the consumers and the producers of coal in India has been that before going in for a high profile technology of coal gasification there can be an intermediate, and in today's context, appropriate technology which will be tuned to the present and the future scenario of economic development, which is upgradation of coal. Today we are transporting coal with 40% ash over distances of 500–800 km which is used by industries. This 40% is a wastage of national resources and infrastructure in terms of transport, fuel, and many other things. A viable immediate approach would be to upgrade the coal at the site of its extraction and transport it, and use the ash without transportation in areas like concrete, road construction, the base of the roads, land filling, etc., as coal gasification requires a large amount of resources which is not with us at the moment.

Carlos Gay (Instituto Nacional de Ecologia, Mexico)
I see industrial transformation as isolated islands – you can transform yourself independently. Pier mentioned that it is global issue, but where is this global industrial transformation being considered? Industrial transformation is two different things to advanced countries and developing countries. It is a cause of concern for developing countries as they see industrial transformation occurring in industrialized countries but not in their homes. Developing countries have subsidiary industries and import a lot of things. What is needed now is for them to enter industrial transformation as direct participants and not merely as importers.

R H Socolow
If indeed most of the infrastructure development of the next two or three decades is going to be in developing countries, transformation would imply doing something different from what was done in the industrialized countries at the point where the decisions could be made to do exactly the same thing. One could also say: avoid repeating mistakes or avoid imitation where it is

inappropriate even if it wasn't a mistake where it was first applied. I have specialized in the field of energy efficiency in buildings. I would regard a good fraction of my career as close to a failure in the sense that buildings are being built all through the developing world with very little sense that the resource throughputs in those buildings, especially for energy, is a critical design feature. Large buildings, office buildings in the downtowns of cities of the world, are being built more or less as they were built 30 or 40 years ago – windows are not different, electric control systems are only marginally different, they are not being rethought of as physical structures.

The purpose of the research programme I was part of in the 1970s was to give some new ideas about that. It was not robust or creative enough, and particularly, information transfer did not occur very well – to the architect community, the planners, and the people who license buildings. For example, while I was in China recently I asked people in the Ministry of Environment and Forests if they were paying attention to buildings that are being built which is going to use electricity from power plants whose environmental consequences they could be regulating. And they said they had not got around to thinking about it. The reason I think it was brilliant on the part of Pier and the others who designed this IT programme to focus on the developing world is that industrial transformation does not mean undoing something but choosing a smarter way the first time. Watching our mistakes being replicated is one of the most disheartening things one can imagine. So there has got to be a breakthrough. There is nothing to import, you have got to invent this. You can import pollution control equipment but you cannot import industrial transformation; you have to invent it.

R K Singh (Bureau of Indian Standards, India)

Two points have been left out so far. One is that in India, at least, we have been frequently utilizing the mineral resources. We are taking minerals for coal and other things also, and we are taking water from underground. But we are not considering the fact that this excess withdrawal may cause some geographical changes like land subsidence which would be a major cause of our disaster. So land subsidence has to be taken into consideration while extracting mineral resources. Second, it was pointed out that we change our lifestyle to a natural way. Would this mean that we should not produce anything or that we could transplant denuded forests with another species of a plant? It is not in fact correct to say that this would improve ecology. The reason being that bioparticulate matters emanate also from the fallen grains, plants, herbs, shrubs, etc., and this will be the cause for allergens. So, if we want to change our lifestyle to nature, then we have to be very careful in choosing the plant which are going to implant in the denuded forest.

R H Socolow
Those are two good examples of the adaptive thinking we have been talking about. The water subsidence, land subsidence, and water management could be very serious problems very quickly in many parts of the world. The economists must turn water into a commodity that is traded, thus greatly reducing withdrawals. This has not been implemented in very many places. But there is no reason why this cannot be implemented in places which are greatly expanding the water consumption relative to those parts of the world where the water consumption is not growing quickly.

Leena Srivastava (TERI, India)
If I may go back to the point made by Mr Gay in a slightly different angle, I agree with the explanation provided and I think that industrial transformation itself is a recognition that things can be done differently, that there are choices and, are we making the right choices across whole range of industries and consumer options before us. But how would this relate to the incremental costs and the global environment facility if they are related to any errors linkages between their activities?

R H Socolow
Our programme has been triggered by the climate process and by the biodiversity convention. So I hope this programme can serve that community either directly or through the IPCC one or two years after Buenos Aires. But what the programme should focus on is developing some longer term research agendas where the results of our research will be needed by the policy makers in about 2004. We must be aware that we are now building up a network. We start by identifying a core project, and then we start research programmes. So it will take a few years before we are fully off the ground. And that is why we do not put all the focus, say on the economic instruments, the decisions makers need between now and Buenos Aires.

Ambuj Sagar (Havard University, USA)
I wish to know how we are going to fulfil the agenda programme of talking about international human dimensions, such as human drivers and the human aspect of this. This seems more to be like a litany of technical issues. The problem is that we are focusing on industrial transformation more from a technical point of view rather than the social point of view. Maybe it reveals that part of the agenda might have been decided by scientists. In the end what is really important is

social transformation. Responding to what Prof. Socolow said, it is not quite clear to me why, or how, one can think about avoiding the mistakes of the North, when the North is still making those mistakes. I think it is a key issue and part of the problem that discussions here and the lot of social issues and the direction the economy moves in is very much directed by, and simulating, what is happening in the North. These kinds of aspects of an industrial transformation are not really coming on the agenda though some of the questions have picked on certain aspects of this. I want to make a plea to push this onto the centrestage to cover industrial transformation relating to social transformation, a relationship between the South and the North and the transfer of ideas from the North to the South.

M S Saeed (International Union for the Conservation of Nature, Pakistan)
I just have one small policy-related question. A lot of times environment is pushed as a separate policy agenda – when that happens, the alarms of some people get going and they get their defensive shields up. If it is pushed as part of each and every policy, it will be much easier to implement it and to get it into the system.

R H Socolow
I wish to clarify that when I speak innovation, I am not talking just about technology. The 'one child family policy' in China is not imitating anything going on anywhere else in the world. It was invented for China's needs. What are the analogues of that and other aspects of the social structure of any of the countries we are talking about? In terms of interactions with places like GEF (Global Environment Facility) it seems to me we can invent. GEF is working with a given set of principles right now that are basically economics based. If this kind of activity can generate a new set of principles to GEF, it should be able to adapt them. We are not constrained much if we look three or four years down the road by any of the institutional structures we have on hand because the world is grouping so much.

Issues in industrial transformation in South Asia

Pier Vellinga (Institute for Environment Studies, The Netherlands)

May I now ask Mr Ijaz Hossain to give us some of his views on the whole topic and the priorities from his perspectives.

Ijaz Hossain (Bangladesh University of Engineering & Technology, Bangladesh)

In the South Asian context, the concept of recycling is extremely important. The loop needs to be very carefully studied. As the countries are fairly poor, materials do not really get thrown away all at once. There is a tremendous amount of recycling which is going on in all of our countries. I consume something and throw it away in the dust bin, there is somebody to pick it up and get it recycled. Unless the material is completely degraded, it is recycled. Even paper which is thrown in the bin is picked up and it goes into a big board factory and comes back as some kind of a packing material. However, we really do not know how long a material is recycled and what the incentives for recycling are; the economic implications of these are have not been studied. And it is important to study this as higher incomes, growth, and prosperity means that the people who collect these things may find it uneconomical to do so. In which case, such kind of recycling may come to a halt. Thus we need to study the kind of incentives that we can probably build into economic growth to sustain it.

The interesting point that I noted in Prof. Socolow's comment is about the battery recycling in America. It exists in some form in our country too. I actually discovered this by accident on my visit to a small town in Bangladesh, where I noticed people on the roads opening up batteries. They extracted the carbon rods to get them recycled. So there is battery recycling but not the scientific recycling which Prof. Socolow pointed out. Another interesting point about recycling is that not all of recycling is actually encouraged in the country. One of my friends works for an amber bottle manufacturing plant. These bottles are used by the pharmaceutical industry. The amber bottle manufacturing industry is now facing closure as the bottles are being recycled and sold at much lower prices.

The jute industry in our country is also in dire straits. The industry which should be the largest foreign exchange earner of the country is facing intense competition and is near closure due to unfortunate policies and total neglect. Also, jute cannot compete with the kind of uses that other plastic and synthetic fibres have. I understand that the jute industry is doing well in India and also in certain parts of Africa. But in our country, it is facing closure and if the government could, it would actually get rid of this industry. This is because the land can be put to more competitive use like rice cultivation. As such, this industry is facing closure and a renewable material resource is being phased out.

Moving to transport in the Asian context, the demand for transport is going up tremendously in all countries. Much of this transport can actually be reduced if three things are taken into consideration. Firstly, improvement in telecommunications. Getting things done in South Asia over a telephone is almost impossible – either the telephone does not work or whoever is supposed to do the work will not respond to a telephone call. So improved telecommunications can reduce a lot of travel needs in Asian countries. Second, towns can be planned such that people do not have to travel half way across the town or all across the town to buy articles of day-to-day use. Travel can also be reduced if your workplace is nearby. In Asia, though the cities are large, many developments have not taken place. A lot of people are still living in shanties. Townships should be developed in such a way that people do not need to move out more than once a week from their houses. These are not new concepts – they have been talked about but have not been implemented. Third, the administrative and banking systems can be simplified such that travelling can be reduced.

The countries in South-East Asia rely very much on nitrogenous fertilizers and this consumes a lot of energy and also a lot of investment. In Bangladesh we set up a large fertilizer power plant which cost 500 million dollars. We shall have to think of ways to develop organic fertilizers and other kinds of fertilizers whereby we can reduce our need for nitrogenous fertilizers. Today Bangladesh's supply is totally dominated by nitrogenous fertilizer. If there is any supply failure, food security would be seriously hampered.

I wish to also focus on behavioural aspects which are changing in South-East Asia. Machines are replacing manual labour. In behavioural aspects, we are becoming, like in Western countries, very individualistic. We rely more and more on materials rather than our needs of communicating to each other. We find happiness in consumption rather than in communication. Our needs have been dominated by economic growth and technological progress. Another important behavioural aspect is that in India, Bangladesh, and Pakistan joint families are being replaced by nuclear families. Therefore, there is a tremendous increase in the number of households in South Asia not only due to population increase but because of the breakdown of joint families, which results in the increasing consumption.

I just want to make one last point of comparison between the material growths occurring in OECD (Organization for Economic Cooperation and Development) countries and developing countries. The OECD countries can think of substitution and technology upgradation. Developing countries, as has been remarked, are trying to follow the same path of growth of these countries from 1920 to 1980. The 60 years will probably be shortened down to 30 years. But the path need not be the same. For example, we could frogleap and go directly into advanced technology. In Bangladesh fibre optics (the cheapest option) is being used in many parts of the country, whereas in Japan it is not so widespread as a change to fiber optics would take time. In Bangladesh, a major portion of the travel of people is to get things done as they cannot be done by calling up somebody. Imagine the material reduction when you go for fibre optics instead of copper and other materials. Also 5 years back the government had said that most places in Bangladesh would not have a telephone for at least 50 years. Thanks to fibre optics many places now have telephones. The government is now considering cellular telephone as an alternative for the conventional telephone system. We can achieve a factor of 10 reduction in material if a cellular phone system is introduced all over Bangladesh instead of a copper-based telecommunication system.

Kulthorn Silapabanleng (Energy Research Institute, Thailand)

Globalization and localization are two polar developments taking place simultaneously. Neither of these can be ignored and I hope we will be able to cover them both. Developing countries should adapt to the new condition of globalization. The developments going on under the UNFCCC (United Nations Framework on Climate Change) ignores the significance of adaptation. Even under this convention, there is no way the developing countries can move ahead of the developed countries that have both the financial resources and the technology. The developing countries need the cooperation and support of the developed countries and a technology transfer would enable the former to avoid the Kuznets environmental curve.

The TERI background paper notes that the consumption rate of energy has been increasing much faster and it is projected to increase much faster than the population growth. This means that we have to think about efficiency not so much in terms of economics efficiency as of eco-efficiency which brings us back to the

Kuznets curve. Eco-efficiency involves two main points (1) technology transfer and (2) management, which also includes the management of renewable resources. At the Thailand Environment Institute, we have just completed a micro hydel project funded by the IDRC (International Development Research Centre). We discovered that the project is very interesting in itself. It not only fulfils the primary objective of energy but also has other spillover impacts. For example, in terms of forest management, the protection of forest cover has also brought about community unity, where villagers work together not only for their own energy needs but to conserve natural resources. In the near future, it would be very important for every country to try to guarantee the rights of management of national resources, i.e., the decentralization of management will have to be institutionalized so that villages can have a greater role of participation. And if we are to talk about the social implications of adaptation or mitigation measures under the FCCC, this dimension of community rights and decentralization has to be researched and also integrated as part of the constitution or other institution of the country. Although an economist myself, I do not quite agree with Dr Gupta that developing countries should switch to rely on market-based instruments. We need a good mix of measures, command and control, and market-based instruments. Also, we should not forget about self-regulation measures. I think it would be premature to leap from one step to the other because in every country there are already command and control measures in the law. Ignoring existing mechanisms which work to some extent, and jumping into something which is new might be too risky as the economists also know little about it. It may not produce the results that we would want to see. So this is another area which needs a lot more research.

I would like to share with you a little bit about the climate change policy of Thailand which is relevant to this forum. We have come up with three principal criteria for formulating the policy for Thailand. The first principle is food security. This is important not only for Thailand which is exporting a lot of food to the world market, but also for the developing countries. So, we should think more carefully about designing a public policy which might commit ourselves to measures that could have a negative impact on food security. But we have little research on potential impacts. So this might be an area that needs further research. The second principle is competitiveness. For developing countries to grow, we still need to find how food can be grown in a healthy way and through the sustainable development. It is easy to conceptualize sustainable developments, but to make it into an implementable policy we need additional reasearch. And the last principle is the social-safety net. This relates very closely to what I mentioned earlier about the need for research before committing ourself to something that may have negative impact on the society. Perhaps our lives would become much easier if we could convert everyone in the world to be vegetarians. Small things like this although said jokingly has much seriousness behind it, especially for India or China.

All along, what I find missing in the discussion this morning is the political context. Eventually when you try to push for either international negotiation or some kind of policy formulation, you cannot ignore the political aspect of the policy making. I do not know how it will be integrated into the existing programme, but it would be important to keep that in mind and somehow to integrate it into the programme.

And the last point that I would like to briefly mention is on technology transfer. In Thailand when we tried to negotiate for joint implementation or AIJ (activities to be implemented jointly), we were pressed for the recognition of intellectual property rights. I think if our partner is sincere about engaging in AIJ, a special clause can be added by waiving aside the intellectual property rights which would create an ideal condition for technology transfer. This is not to say that we do not respect the intellectual property rights but we also want to ensure an ideal condition for the transfer of technology.

Pier Vellinga

Thank you for your comprehensive list of what you think would be necessary to strengthen this programme.

I look at this industrial transformation exercise essentially in three major blocks. One is the traditional block related to technology *per se* where you identify a technology and the connected processes, and then get into the business of technology transfer on standard routine lines. This is the only component which has been traditionally emphasized when it comes to technology or industrial transformation. The second component, which is the economic components, is not given much importance by researchers but is given top most priority by entrepreneurs who are going to implement this transformation. The entrepreneur looks at industrial transformation only from one perspective: Is it going to improve his benefit stream? If it does not improve his benefit stream, he is not interested in the pollution control, pollution prevention, or environmental conservation. Therefore, the economic component, whether in terms of direct investments, one time investments, lifelong investments, incentives, or subsidies, is a whole box of economic tools which have a strong bearing on whether industrial transformation succeeds or not. Arising out of the technology and economic tools, comes social implication because the policy makers and the researchers are aiming at all these changes in order to bring about a transformation in the quality of life of the masses as a whole. Therefore, social impacts and social issues become very predominant. Thus the focus of research, discussion, and dialogue has to be not merely on technology *per se* but on a much broader and wider scale. Since liberalization started in India six years ago, we have come to realize that research has to start at the policy level. Are the policies attuned and framed in such a way that they will facilitate industrial transformation, which is required for a better economic return and better social outputs? If the policies are negated, there will be a struggle at every step. We need to evaluate whether the different sectoral policies are coherent or not. If they are not, you end up with situations which do not lead to sustainability and sustainable development even in terms of bringing into focus the industry and the management issues which could lead us to the type of enhanced output streams which are the objectives in these exercises.

The second area of concern is the planning process. By and large in the Indian subcontinent and also in the South-East Asian countries, the whole planning process is guided by the financial inputs, capital investments, and the constraints which are governing them. If we look at it from the climate change aspect or in terms of our lifestyle, or in terms of sustaining the whole process of development, the centrepiece is natural resources. Very few of those natural resources can be supplemented through imports. Whether it is land, air, water, biodiversity, or biomass, either you have them or you do not have them. Which means that the whole planning process has to be guided by the components of sustainability within an eco-system on the basis of availability of these resources and the budgets available. If it is the natural resource component which is going to dictate the development portfolio, then capital investment becomes a secondary issue in terms of determining which particular portfolio should be selected. If this is disregarded and some esoteric technology is adopted, we may find that it has not given the results which were expected or which it was giving somewhere else. We have been talking in terms of appropriate technology, but unfortunately it is often missing when it comes to technology transfer, or application of technology, or even in trying to identify the technology which will solve our particular problems. Allocation of resources on a regional basis for sustainable regional development gives a totally different portfolio of development compared to this capital investment scenario. The location of the facility and the location of the development activity has to be considered while preparing a development portfolio. If the constraints of resource availability either in our ecosystem or transfer from one ecosystem to another is not recognized, we end up with portfolios which are quite unsustainable. So if we shift from this capital investment criteria to the natural resource constraint criteria, we get a totally different kind of development mix which has better chance of becoming sustainable.

The third component is transformation in the industrial processes and the products. In both of these areas in South-East Asian countries, and more so in the Indian subcontinent, we have been guided in the past entirely by the experience of the West. We end up copying what was done in industrialized countries, thereby pushing demand for various kinds of products which in turn put pressure on the natural resources. Rethinking in terms of the processes, modifications, re-tooling, and also the new products, modified products, etc., is needed.

What have we learnt from research, whether basic or applied? How much have we been able to implement, and to what purpose? I hope that the research on industrial transformation, would be meaningful and pointed to the extent that it gets implemented and gives the types of results with which it was envisaged and started.

Quite often we assume that the component which is missing is technology, we think that with the right technology, things will happen extremely smoothly. But this does not happen. The delivery systems are your organizational structure and the mechanisms which are in place including the administrative set-ups. If the administrative set-up has not been able to deliver in 100 years, I do not think that it will start delivering only because of technology. Technology transformation cannot bring about change unless we also have organizational restructuring. That is an area which requires tremendous research, but it is being neglected. Unless we couple it along with the other research, we will only have research findings but no implementation.

Post tea session

Pier Vellinga

All issues must be simultaneously looked into when addressing a specific problem. That means that you must really define your research question very well for only then can you bring in more disciplines into a topic. There has been a lot of talk about energy use, materials, and choice of materials. Well, one topic for research can be the energy production and consumption and it could have some relation with the materials. Another topic, as I mentioned earlier is materials processing and its use. But the emphasis was very much on recycling of materials, the economic incentives, and the consumer aspects of collecting materials, and how that works. The third topic mentioned was the focus on energy, where we look at employment and industrial restructuring. It could either be under energy or in a cluster like energy and materials processing. Let us look at this cluster and the restructuring of the economy and the effects on employment. Specific transport needs and telecommunications was mentioned as the fourth topic. There was not much talk on water, which is a very important topic and is being studied by a lot of research groups from a human security point of view.

Robert O Williams (United Nations International Development Organization, Austria)

I work for UNIDO (United Nations International Development Organization) which has its headquarters in Austria. Within UNIDO, we have developed an approach to our work that may make useful contribution to the overall framework that you want to discuss first and this may be of some help to you. I would stress, however, that we are not a research organization. Unlike UNESCO (United Nations Educational, Sceintific and Cultural Organization) we do not actually support research within a specific context of industrial development and the industrial process improvement itself. We have over the last decade certainly moved our activities towards the promotion of what we call sustainable industrial development. Interesting enough, we organized conferences which contributed mainly to Rio de Janeiro Summit, which we call the ESID conference, Ecologically Sustainable Industrial Development, in which we embraced a number of concepts that Prof. Socolow presented. People did not like the idea of ESID, which was a little ahead of its time and they wanted us to call it 'environmentally sustainable industrial development', which seemed to be more palatable. And now the world environmentally has been dropped and it is just 'sustainable industrial development'.

Cleaner production and environmental management are rather pedestrian concepts compared to some of the much more ambitious ideas that you are talking about here. But it is worth mentioning, perhaps, that for us and for many others working on cleaner production and pollution prevention, it is still in early stages, it is taking a long time to get industry to make even a small transformation, compared to the transformation in terms of introducing much more efficient technologies. Thus, we focus on three areas: employment, environment, and competitiveness. Employment has already been referred to as something that does not exist in plenty, but that which one may wish to add. What will a sustainable future look like from the standpoint of employment? The available body of literature tends to focus on the impacts on employment in developing countries of introducing sustainable development. Environment too has been already broken up into energy, water, etc. Competitiveness seems absent and the issue of globalization has been introduced in some of the introductory presentations. So you might want to consider that in developing countries, industry is going to compete in the international market now. It is going to be an important issue. These may be considered as possible components of the research agenda.

M A Qureshi (National Institute of Science Technology and Development Studies, India)

I wish to make two points. One is in the context of the study of environmental defects which should focus on a larger area than concentrate on one place. It requires certain conceptual approaches, and also the theoretical backup, which has to be based on the use of local resources and skills. As somebody pointed out earlier, information technology plays a major role in the blending of traditional and modern technology. People talk of alternatives, but we have not been able to provide a comprehensive intellectual back-up for this kind of development. While for urbanized industries a full techno structure, information, literature, etc., are available, a new approach for rural areas is required. Another point is that economic growth and urbanization are strongly linked in the present day context. Now there is a need for devising technologies for sustainable urban living. The third point is that the South Asian countries, while trying to work together, are trying to develop mechanisms. There is a need to integrate the market, which has not been done so far. And there are certain areas where niches exist in different countries. In this context, there is a need to integrate the whole production within these countries.

Anand Patwardan (Indian Institute of Technology - Mumbai, India)

One area which I found people talk about peripherally is the whole notion of institutions. If we look at the industrial structure today, there is a variety of institutions, some of them financial, some of them regulatory, some of them policy, and some formed of industry associations. So there is a variety of institutions that really affect how industries can and do respond to changes in their environment. Industries or firms have to function within this sort of institutional structure. Thus we need to understand what these institutions are, what roles they can play, and more importantly, how we can leverage them for intervention. In industrial ecology, for example, how can one use the entire apparatus of central and state pollution control boards, which is basically a large institutional structure of regulation, to try and help industries which are trying to prevent pollution. There is a lot of interesting analysis or research that can be done in the area of institutions. I suggest that we use the notion of linkages as a strategy for prioritizing or identifying specific research topics.

Let me give you a couple of examples of what linkages might mean. First, is the notion of competitiveness. Today, if I talk to Indian industrialists in the language of competitiveness and productivity, they are willing to listen to me even if I want to make a point about the environment. And many firms today, facing the pressures of a globalized economy, are willing to consider being more environment friendly as a driver for re-examining their processes or looking at opportunities for pollution prevention or value addition to waste. So we can use environment in many cases similar to the way we use the notion of quality. This brings us to the notion of standards; a lot of firms today are complying with ISO 14000 because it is a prerequisite. Now the issue is: in what way can we promote the notion of industrial ecology?

The other linkage is with institutional structures. A lot of industrial activity in India is organized around industrial estates. Different states have industrial development corporations and there are industrial estates around which a lot of activities are organized. In a way, the industrial estate is a natural place for trying to work out industrial ecology. Can you try and close the loop within an industrial estate and target it to industrial locations? It is already in practice but to what extent can we leverage it for achieving environmental goals as well? I think looking at linkages is a way of trying to identify the interesting research questions. With regard to diffusion, we need to look at the whole notion of technology diffusion and identify barriers or constraints for adopting new technology or new ideas. Where we have specific technological interventions to improve the process, we should try and defuse those interventions more widely throughout the industry. That may be an important research topic to look at. Thank you.

Manubhai Shah (Consumer Education and Research Centre, India)

I only want to make one comment on one of the earlier presentations. A lot of work is done in India with the help of UNDP (United Nations Development Programme), whereby jute is being developed more as fabric for apparel, rather than as the traditionally used packaging material. This is because packaging material has caused a lot of problems, particularly in items like cement. Its porosity has affected workers who have to pack cement in it and also consumers because of the loss in weight. But the blending of jute with other fibres has been successful.

I also want to highlight some areas where safety is involved along with environment, such as agricultural practices and use of pesticide sprayers, which are creating a large amount of problems. The sprayers have been found to be very defective as they lead to large wastage of pesticides, which in turn affects the workers, mostly women. It affects the soil and ultimately the consumers because of the residues of pesticides in food. Therefore, again the question will come up in terms of testing of the sprayers, publication and publicity of the information, improving the quality of that, and effecting the quality of life.

Can we now have a second look at solar water heaters. How do we operationalize it in terms of having a research agenda? Why have those developments not become a part of life and what were the handicaps if we take that up for research? Thus with smaller amount of input we can have much larger output or benefit because a lot of technological work has already been done.

My organization is particularly interested is two areas where we have already started comparative testing of electrical appliances. We are planning to air the dimension of energy efficiency of each of these electrical appliances, publishing and publicizing the said information and again conducting research on how much of this information percolates, what changes take place at the management, or the manufacturing level periodically. Do the consumers begin to change their habits in terms of preferring energy-efficient appliances? Or do they go by other considerations of colour, aesthetics, size, etc. Another area of interest is the testing of the consumer products to find out which of the brands are environment friendly in the context of energy consumption, water consumption, biodegradability, and end packaging material in terms of re-use or recycling. This is one area where a large amount of work has been done abroad, particularly by consumer products testing laboratory. And again the research would be on the basis of buying patterns or consumer preferences and how those consumer preferences can be influenced so that they buy environment friendly products. This will obviously lead to our sustainable development in their sense of the term.

Leena Srivastava (TERI, India)

I just wanted to seek clarification on a couple of points in relation to the framework. One was about employment in the framework that you had. Employment is really an integral part of every cell, in terms of its current influence and choices. It is thus a driving force and a consequence. The second point that I wanted to make was in relation to human dimension. The IHDP really tries to understand the value systems, the choice, the preferences of consumers that are driving a particular type of activity. The impact of an industrial transformation on the value systems, on changing the consumer preferences and choices in a particular manner need to be looked at. For example, in the television industry in India, with the opening up of the market and new schemes that are coming in, there are promotional activities which are consciously seeking to increase to a very large extent the use of these appliances and devices. So, it is a full circle. Lastly, I would have thought that in addition to the three drivers for information technology, policy, technology, and consumer choice, the fourth, awareness and information could be added because it is a very critical input required at all the three levels and it needs to be integrated with all the first three in order to bring about industrial transformation. To a large extent that should also drive the research agenda.

S Maudgal (Ministry of Environment and Forests, India)

I wish to make just two observations. One is about the specific areas that industrial transformation requires which can be added for consideration using known tools and development of new tools and techniques. And it could be gainfully utilized in terms of clubbing together tools such as LCA, resource accounting, environmental audit, with forward and backward linkages. For example, in the energy sector coal mining, transportation, power generation, distribution from the concept of LCA, resource accounting and environmental audits can be together taken up in order to demonstrate the economic returns which are possible and how sustainability can be built into the whole system. This will help in terms of developing tools and at the same time demonstrating the efficacy of the tools which are being suggested. The second area assumes a lot of importance in the context of Asian countries and the Indian subcontinent. In terms of globalization, the whole business of patenting, intellectual property rights, international agreements, and conflict resolution the areas which are not as cut and dry as they seem to be. A lot of understanding, interpretation, and research is called for in order to make my entrepreneurs comfortable with these concepts, which are in terms of both cooperation and technology transfer, etc. That could be an another area which can be a sub-sector of the globalization or it could be added as a separate one.

Sumeet Saksena (TERI, India)

In the context of industrial transformation, many specifics were mentioned: mass balance, auditing, life cycle analysis, etc. I would suggest that we also seriously look at risk assessment and risk communication because, I believe, that it is risk assessment which for the first time brings us in touch with the human dimension, more specifically human behaviour. If we are serious about connecting science to human behaviour then risk assessment is something which cannot be ignored. More importantly, it is risk communication that we should be focusing on. Risk assessment should not be done for its own sake but should be connected to communication. Finally, there are some more specific questions: How do consumers perceive environmental risk? We know some amount of research has been conducted to look at how consumers or people react to potential financial risk, but there is very little understanding of how consumers react to environmental risk.

R K Pachauri (TERI, India)

Before I turn to Prof. Vellinga, I just wanted to mention a couple of points that occurred to me when I listened to your interventions. I think there is a need to look at this whole business of rural industrialization. How does one decentralize the means of production and the manner of production. This I feel could be an area in which research could be carried out from various angles. There was a discussion on institutions and how they should really function, there was a question of scale of industry. But this again is an area where one can do a lot of meaningful work. And when we look at institutional structures, it is not enough to merely look at the structures themselves, but also the kinds of powers, and the kinds of instruments that they would have at their command and what the efficacy of those instruments would be. So, there is a huge research agenda over there which need to be structured.

Prof. Manubhai Shah talked about the research agenda for technology development, he gave the example of solar water heater. But, I think there is something lacking in the manner in which we in this country interact between research institutions, industry, and government. Therefore, there is something lacking by way of orientation towards taking the fruits of R&D to an actual product or process. In other words, something that has commercial value, which should be looked into. I am sure to some extent this issue would be relevant to other countries in Asia as well, particularly South Asia. The technology transfer issue is an important one. Dr Maudgul talked about patenting, intellectual property rights regimes. I think this could fit in neatly into some of the technology transfer issues, where I feel barriers and misperceptions exist. And I think there is a need for refinement of the system which we could deal with. The last point I would like to make relates to what Seiki mentioned about the interface between the various elements of the programme. I felt that one area that perhaps needs some attention is the area of soil degradation and this has important implications on food security. It has important implications for other dimensions that are human in nature but have other dimensions as well. I feel given the fact that in modern industrial state there is a major impact in terms of soils because of the use of fertilizers, pesticides, agricultural practices, deforestation, and water usage that this is an area that needs some process.

Pier Vellinga

I will be ready to try to put all I have heard together. Let me tell you, I will not do the research. So I will mainly challenge you to decide on where to put your eggs, in which basket. And maybe, it is not even completely important which basket, because as Seiki said, an initiative is important because it brings together the various schools of thought, the technologies, the macroeconomists, and the political scientists and consumers perceptions. That is very important and it brings together researchers from various parts of the world who intend to work on policy decisions regarding the global environment. Let us also understand that this workshop will come up with some topics which will be carried to the Science Planning Committee, of which Robert Socolow and Dr Pachauri are a part. Referring to what Prof. Seiki said, what will the society look like after we achieve the factor ten, for example, when reducing the burden of energy on environment? Surface economies are sustainable, with which we have economic development. But, the right question to be asked is would we be happy with such an economy? This brings us back to the question of employment. From all the discussions we held in IHDP-IT, we can integrate it either in energy and materials or in food and transport. But if you make it as a topic itself, it will be a topic for economists only. It would not then be related to consumer oriented people unless the focus is on specific needs like energy, food, and water. How much employment does it take to bring these services?

Another thing is the management of transformation. Well, I think that is all the topic is about. Even in the field of food, we must get rid of fertilizer input at present levels, we must get rid of pesticides. And maybe, we also need to change to much bigger share of vegetarian food. That is what the programme is about, it is about transformation and its management. Again, in the social science agenda the behavioural aspects should be integrated in our study programme. Jesdapipat talked about adaptation, but this is not part of our agenda. Although it is important to talk about industrial transformation, it could be a part of the agenda only when you talk about food. If food is a big topic then you must look into climate. I am not sure whether to climate change itself has a lot of influence on energy.

The decentralization of industrial production has been emphasized, and I find that is a very challenging topic as you could decentralize a lot of production because of information technology. Right now it is all centralized. And I am sure for the next 10 years it will be centralized. But our research programme should also develop the ideas and experiments that are ahead of time and maybe some interesting projects based on decentralized production systems. Renewable energy could have new emphasis there. You could look at decentralized production again when you look at food or food processing. In many countries here, the food grown goes to the central processing units, and then it goes to respective consumers. It requires a lot of transportation. The top priorities of Thailand in food security was mentioned. The political complex includes the incentive structure. If you start coming up with proposals to change it, it is absolutely political. Thus, we should be aware of what policy makers and governments are discussing right now and see whether we are in tune with them or whether we should help them to move to some further steps. I think indeed transformation is about trying to set some goals. They may not be the right ones, but then from these goals you are able to arrive at the transformation path.

Meanwhile in 5 or 10 years the goals may change. So you should also test how robust the initiative for other goals is and find out how much we have learnt and how much have we been able to implement the existing research. I think whatever column you choose, you can take that as an interesting research topic to make an inventory, what is on the shelf, what has been picked up, and what not, and why not. Thus, the contribution of social sciences crucial there. It may sound that the UNIDO is focusing on incremental steps that have to be made, while the research agenda and research takes a lot of time. We also must go beyond these incremental steps. As mentioned by Patwardan, the institutions are integral part of incentive structure. Dr Shah asks why research results have not been introduced in society. I think that could be part of either food, energy, water, or transport agenda. And of course, along with comparative testing of electronic appliances, we could do comparative testing of completing vertical industries. Why is one energy company performing better than another energy company? Why is that one electronics company, like the Sony produces better appliances than Philips or another company? By comparing them and advertising the comparison, you can promote change. This can also affect the stocks. It is good to connect, say, the financial agenda with the production agenda.

Appendices

Proposals

- Rural ecological engineering for refinement of energy use through renewable energy technologies
- Material flow and recycling approaches for steel, paper and pulp, and coal

Programme

List of participants

Rural ecological engineering for refinement of energy use through renewable energy technologies

Background

In developing countries the availability of energy has not kept pace with the demands of the growing population and the national development plans. A probable reason for this is the current pattern of development which gives great weightage to commercial energy. This has led to large increases in the consumption of electricity and oil, resulting in inequities, external debt, and environmental degradation. What is often neglected is that the majority of the rural population continues to heavily rely on traditional biomass fuels for meeting their daily energy needs. For meeting their cooking energy requirements, villagers depend predominantly on biomass fuels like wood, animal dung, and agricultural residues, often burnt in inefficient traditional cookstoves. The main fuels used for lighting in the rural households are kerosene and electricity. Irrigation is mainly through electric and diesel pumpsets. The rural industries and the transport sector rely primarily on animal power and commercial sources of energy like diesel and electricity.

In most countries despite the rapid pace of economic development, the expected shift from biomass to fossil fuels has not taken place in the rural areas. Cooking, the largest biomass utilizing end use, continues to account for nearly half of all the energy used in the country. However, most energy planners and policy makers often overlook cooking and other rural energy needs. While it is assumed that grid electricity is utilized for lighting, biomass and kerosene-based devices fulfil the lighting needs of households even in the electrified villages.

ural energy scenario in India

In India, the household sector is the most energy-consuming sector, accounting for 75% of the total energy consumed. Cooking is the largest energy-consuming end use. It accounts for nearly 90% of household energy; lighting and space heating consume the rest. Biomass fuels account for 85%–90% of domestic energy and 75% of all rural energy. Among the biomass fuels, fuelwood consumption is significant amounting to 200 MT (million tonnes) per annum, most of which is collected in the form of twigs and branches by women and children. On the supply side, it is estimated that the annual sustainable yield from different land sources is about 86 MT. Among commercial fuels, kerosene is predominantly used for lighting. Recent estimates put the total kerosene consumption for rural lighting at 5 MT. This trend is likely to continue in the near future. The agriculture sector is the second largest energy-consuming sector in rural India. Here, animate energy (human and draught power) accounts for more than one-third of the total energy consumed. Irrigation is the most important end use; there are about 10 million electric and 6 million diesel pumpsets in the country.

The demand for biomass in rural areas is expected to grow substantially in the future. This would lead to further deterioration of the natural resource base. The adverse impact of this trend on the quality of life of the rural population, especially women, will be profound. The time spent by women in procurement and processing fuels for cooking is substantial. On an average, about two to six hours and 4–8 km per day per family is spent in collecting about 10 kg of fuelwood. As fuel scarcity grows, the rural women are forced to spend more time and travel longer distances to collect fuel, fodder, and water. They spend long hours in poorly lit, smoke-filled kitchens, cooking on grossly inefficient cooking devices. The health impacts of this situation are serious and often fatal.

Government interventions

To redress these problems, several efforts have been made both by government organizations and NGOs (non-governmental organizations). These efforts include national programmes for rural electrification and the promotion of renewable energy technologies like biogas, improved cookstoves, and solar cookers.

Recognizing the need for developing and utilizing renewable energy sources to meet the increasing demand for energy, the Government of India formulated programmes through its various committees, which were implemented by different ministries. These committees include the Fuel Policy Committee (1974), Working Group on Energy Policy (1979), Advisory Board on Energy (1985), and Energy Demand Screening Group (1986). Initially, the major thrust was on fuel substitution by supplying kerosene through the PDS (public distribution system), network of fair price shops, and power through rural electrification. It was then acknowledged that these efforts need to be supplemented by NRSE (new and renewable energy systems) to supply energy to both rural and urban areas of the country. The programmes relating to NRSE also had a direct relevance to afforestation, improvement in the environment, energy conservation, employment generation, upgrading health and hygiene, social and women's welfare, providing water for drinking and agriculture, and bio-fertilizer production. These programmes helped in the conservation of commercial sources of energy and were environmentally benign. Under the Eighth Five-Year Plan (1992–97), the newly formed MNES (Ministry of Non-Conventional Energy Sources) proposed further expansion and intensification of programmes on improved *chulhas*, biogas, and solar thermal devices. The major thrust would be on large-scale commercialization of low grade solar thermal systems, fixed and portable wood-stoves, and small (1–2 m^3) fabricated biogas plants, and their standardization. Solar photovoltaic systems would be utilized to meet the lighting needs especially in far-flung rural areas.

The programmes were thus expanded under MNES and implemented through state nodal agencies and block and district cells. However, in spite of the existence of these programmes for nearly two decades, their impact on the rural energy scenario has been limited.

Objective

This study analyses the institutional, administrative, technical, policy-related, and economic learning processes necessary to remove barriers and promote broad dissemination of techno-economically viable, environmentally important, and socially relevant renewable energy technology so that they become part of the mainstream rural energy system options.

On the consumption side, it will assess the present trends in energy consumption in the rural areas and make future projections based on the same. On the production side, the project will focus on exploring the feasibility of energy-efficient and renewable energy technologies for the rural community. It will also focus on the integration of renewable energy technologies to promote decentralized production. The options suggested as an outcome of the study, in turn, would generate employment and would incorporate

- efficient use of local resources e.g., crop residue;
- upgrading local skills;
- generation, adaptation, and commercialization of technology; and
- an appropriate technology delivery system.

The broad framework of specific technologies could be

- small-scale production by blending modern scientific knowledge and traditional knowledge, and
- supporting rural industrialization though the use of renewable energy technologies in such new industrial areas as agrotechnologies for aromatic and medicinal plants, food processing, and sericulture.

Coverage

The area of focus of the study will be in the developing countries; preliminary discussion with some of the partners have indicated that the project can concentrate on countries like Sri Lanka, Thailand, Bangladesh, and China. Discussions are currently going on with different institutes in these countries for a collaborative effort for the project.

Methodology

Consumption systems

It has now become imperative to move away from this commercial energy oriented development process and look for appropriate energy solutions. With the rural population poised to cross 750 million by the turn of the century, the energy requirements would be enormous and there is a need to develop innovative approaches to deal with the rural energy problems in the future. Increasing supplies of commercial fuels such as kerosene or LPG (liquefied petroleum gas) is one option, but not feasible in the near future. For example, kerosene is supplied mainly through the PDS. Given the highly decentralized nature of PDS, there are several administrative loopholes (pilferage, diversion for other uses, etc.) in its operation (for instance, in several states, a part of the kerosene is illegally routed for use as transport fuel in combination with petrol). There is an obvious need to strengthen the PDS. Even then, it is unlikely that commercial fuels can be increased in supply significantly because of competing demands in other sectors like industry and transport. Given the large import bill India foots for petroleum products, the rural sector is unlikely to be given preference. Other barriers such as inaccessibility, poor paying capacity of rural consumers, etc., will limit the use of commercial fuels in the rural areas in the coming years.

Proposed research

- Effectiveness of policy measures to promote sustainable consumerism – several policy measures have been taken by the government, especially by the MNES; the efficacy of these measures is still to be ascertained.
- Analysis of energy consumption patterns in the domestic, farm, and rural industrial sectors.
- Role of local markets, government, e.g., PDS in achieving consumer's needs and preferences for fuels.

Environmental impact assessment

This energy use pattern has serious implications both on the environment as a whole and on the users. Fuelwood requirements have contributed to degradation of forests; shortages are reflected in women having to travel longer distances and spend more time in collecting fuelwood, switching to inferior fuels, and even altering food habits to reduce fuel consumption affecting the nutrition levels. Given the exploitation rate of natural resources, this situation is likely to worsen in the years to come. Rural energy systems are further strained by the inability of people to shift to commercial fuels like electricity, LPG, and kerosene because of low purchasing powers and limited availability. A detailed environmental impact analysis will be carried out and will focus on the

- assessments of current technologies with a view to determine their impact on indoor air, and
- assessment of related respiratory and other diseases, particularly in women and children.

Production systems

In the majority of developing countries in the Asia-Pacific region, most renewable energy technologies have been forcefully promoted as solutions to the energy problems before the technology reached a level of maturity warranting such an effort. Aggressive promotion led to unreasonably high expectations from these technologies, and the effort, either explicitly or implicitly, gave the impression that they were the answer to all the energy problems of the country. This has become a serious barrier with the widespread feeling, among those associated with the energy policy making, that the possible role of renewable energy technologies is grossly overestimated.

The present project focuses on minimizing the technology barrier by identification of appropriate system design and integration of renewable energy technologies.

Proposed research

- Assessment of current energy production technology in practice with respect to pollution abatement and production cost.
- Feasibility of appropriate hybrid renewable energy technologies to replace the existing technologies.

Analysis of policy instruments

India has had an active renewable energy programme for over a decade, during which a number of renewable energy technologies based on biomass, solar, and wind resources have been disseminated. Among them, biogas plants, biomass gasifiers, improved cookstoves, and solar photovoltaic systems have been targeted mainly to meet the rural energy requirements.

The subsidy-driven renewable energy programme ran for almost a decade before the government reformulated the strategy in 1992 by promoting a few technologies (wind, small hydro) commercially. The subsidies were removed and fiscal incentives coupled with soft loans were introduced to facilitate this process. However, most rural renewable energy programmes continue to enjoy subsidies. Thus, the MNES programme continues with a dual strategy.

With this approach, the programme has made some progress – 2.2 million biogas plants, 19 million improved cookstoves, and several thousand photovoltaic systems have been distributed. However, the impact of the renewable energy programme has been mixed: many technology programmes have experienced serious failures; and the overall impact has not been significant. For instance, not more than 5%–6% of the rural households have biogas plants or improved cookstoves.

There are two sets of barriers limiting the impact of renewable energy technology (1) related to the technology integration for cost reduction and enhancement of reliability, and (2) related to implementation where the operational and capacity constraints are hampering the performance and long-term sustainability of the renewable energy technology systems. The current proposal attempts to address both the issues by identifying key policy instruments necessary for removal of these barriers.

Planning

The target-oriented approach has led to a number of problems in implementing the programmes. Since the emphasis has been on fulfilling the target number in a given year in order to utilize the funds allocated, proper attention was not paid to aspects like quality control, user awareness, adequate training for those involved in physical installation, creating operation and maintenance structure, etc. Also, as the government functionaries at the local level (block and village) have to meet targets in various other rural development programmes as well, they could not pay the attention the renewable energy technology programmes deserve. In this respect, the track record of the NGOs has been far better.

The project will focus on a comparative analysis of the approaches adopted by the NGOs and the government. It will also identify the modalities and the methodology for active user participation with special emphasis on women.

Implementation

In many countries the renewable energy technology programmes, especially in the rural areas have been perceived as 'government subsidy' programmes which treat people as only 'beneficiaries'. Local people, especially women who are the main users of these systems, have been seldom involved in either planning or implementation of any renewable energy technology intervention programme. Thus, people have had no institutional and financial stake in the programmes, and at the slightest hint of a problem with the systems have abandoned them and gone back to the earlier conventional systems. Expecting the government machinery to take care even of the smallest problems, they have preferred to let the systems become dysfunctional rather than invest in their repair, especially in absence of local infrastructure to deal with such problems.

The project will focus on a detailed analysis of the implementation mechanism being adopted in the Asia-Pacific countries and suggest measures required for effective programme implementation.

Building capacity and information barrier

Proper and adequate training for various interest groups involved in the implementation process and creating awareness among users on the functioning of various systems have not received any importance in most renewable energy technology programmes. There have been several instances where a biogas plant failed because the household was not told the ratio in which dung and water should be mixed for the feedstock, and an improved *chulha* consumed more fuel than a traditional *chulha* because the user did not know how to adjust the damper. While the omission of imparting such basic information has resulted in systems not working due to even minor problems, the lack of rigorous training for the masons constructing biogas plants or *chulhas* has resulted in poor quality, leading to system failure.

Human dimensions

Technological development and dissemination in developing countries have often ignored the human dimensions that are critical to their success. Studies by TERI and others indicate that the following factors often lead to a growing dissatisfaction and uncertainty vis-à-vis biogas technology.

- No follow up or repair services
- Lack of training on usage and maintenance
- Incomplete information on technology, usage, and benefits
- Faulty construction (dome leakage)
- Minimal involvement of beneficiaries, especially women

The proposed study aims to analyse three kinds of stakeholders: the domestic users who would benefit from the programmes, rural entrepreneurs, and those implementing renewable energy programmes. This could be done in several different locales, and with different implementing agencies.

- *Domestic users* The study will first identify the different needs of users, and the importance of energy among these needs. The socio-economic characteristics of different users will also be observed. A study of time budgets and mobility patterns of different domestic users will be carried out. Finally, users' perceptions of renewable energy programmes and their access to information will be noted.
- *Rural entrepreneurs* The analysis of rural entrepreneurs will begin with an identification of their energy requirements, and will be followed by the identification of the infrastructure that they would like in place and the constraints that they face.
- *Implementers* The perception by implementing agencies about their own role and user needs will be studied. The extent to which they have sufficient and well-trained extension workers will be gauged. The adequacy of the repair and maintenance services will be assessed.
- *Information dissemination and training packages* This should help identify the ways of promoting better information flows between users and implementers and to train extension workers.

Material flow and recycling approaches for steel, paper and pulp, and coal

Introduction

Industrialized societies in third-world countries are undergoing a period of transition from 'cowboy economy / free-lunch economy' to energy- and resource-efficient systems. Environmental pressures are the forces driving the new changes. During the last couple of decades, it has been amply demonstrated that emissions from industrial sources are major contributors to environmental degradation. Raw materials are extracted from the earth's crust, transformed into products, and ultimately discharged back to nature as 'wastes'. Such a dissipative cycle has led to a search for sustainable ways of production. In such a scenario, substances which do not fit in natural cycles are designed and conceived such that they can be re-integrated into the system.

Sustainable production technologies involve a comprehensive study of resource and environmental management systems. Industrial ecology has emerged as a distinct school of thought to implement such technologies. It is a mechanism to understand and interpret the synergy between natural and man-made systems. The aim is to develop a framework that targets sustainable human activities by minimizing material and energy usage and associated environmental impacts on the ecosystem. Ideal industrial ecosystems close the material loop by making maximum use of recycled materials in production and minimizing waste generation, and re-evaluating wastes as raw material for other processes. The industrial ecology vision encompasses industrial sectors and national or international boundaries (Graedel and Allenby 1995). Industrial metabolism, LCA (life cycle assessment), design for environment, pollution prevention, and product life extension are important research tools for industrial ecologists. Each of the tools delineates a sphere of sustainable production–consumption entity.

Energy and material flows through the processes of extraction, production, consumption, and waste disposal are essential components of industrial metabolism. The guiding approach is the fundamental law of nature – conservation of mass, i.e., mass can neither be created nor destroyed. Mass balance research is closely correlated with economic analysis. Intensity of material production and consumption is an indicator of social affluence.

Historical trends starting from industrial revolution have demonstrated that industrialized economies have observed a phenomenal increase in the material utilization. Fears of diminishing resources and damaging environmental impacts have retracted the trends. Emerging concepts of industrial ecology, dematerialization, and eco-structuring have become an integrated part of research folders of policy makers and planners.

The IHDP (International Human Dimensions of Global Environment Change Programme) has identified 'industrial transformation' as a priority area on its research agenda. Industrial transformation research focuses on the transformation of the activities related to the flows of substances, energy, and materials that negatively affect the global environment (IHDP Science Plan 1998). Industrial transformation research can be applied at a number of levels: global, regional, national, industrial, or plant specific. The South Asian Regional Conference of IHDP in New Delhi, April 1998, has recommended a regional level research on 'Material flow and recycling approaches for steel, paper and pulp, and coal'. The multi-disciplinary research will involve institutions from at least three different countries to project integrated regional perspectives on industrial transformation.

Objectives

The principal objective of this research is to analyse material flows of steel, paper and pulp, and coal at a regional level within the economy–environment linkage and determine how human needs and preferences can influence industrial transformation activities.

Research framework

Sustainable development coupled with economic liberalization is widely perceived as an opportunity to avoid environmental damage and enhance performance efficiency. Growth inertia of the early 1980s has paved the way for restructuring, increased demand for products in competitive global markets, and realignment of focal issues. Unlike industrialized countries, the demand for products is largely unmet in developing countries, severely affecting the dynamics of production-consumption subsystems. The resulting intensive industrial activity adopted as recourse to bridge the gap has a dominant bearing on the priorities and policies. Consumers, the major stakeholders, are usually ignorant of the background technicalities of the products they buy. Exchange of notions on product preferences and needs between producer and consumer is non-uniform and sporadic. The approach should be to build an understanding and transparent relationship for sustainable production, use, and disposal. Producer–consumer associations under the 'human' domain need to redefine the objectives and orient their activities to target cleaner and safer habitats.

IHDP stipulates a research framework for industrial transformation activities covering the following three fields (IHDP Science Plan 1998)

1. *Macro-systems and incentive structure* or the set of rules and incentives that are or have been important for production and consumption processes, and an understanding of the related environmental resource use including the flow of materials and substances affecting the environment.
2. *The production system* including the technologies applied in view of the organizational and economic system and their setting.
3. *The consumption system* including the needs (abilities and opportunities), demands, and preferences of consumers and the ways in which consumers express their preferences.

Research methodology

Macro-systems and incentive structure

Fulfilment of needs and demands of the masses deems that national material flow accounting be conducted. Quantification and assessment of inputs and outputs to the national economy help provide benchmarks for improvement and avenues to explore new paths of development (Wernick and Ausubel 1995). Linkages between national material accounts and environmental performance are yet to be ascertained in developing countries. Research agenda to develop such linkages can frame strategies to identify alternative materials, which can satisfy human wants with less environmental damage (Wernick and Ausubel 1995). Material flow analysis incorporates an LCA approach to construct inventories of resource consumption and residual wastes. The LCA links these inventories to recognized environmental impacts in an objective manner. Integration of material flux attributes is important to serve as a reference source to simulate and compare macro-scale trends in the economy and influence policy interventions. Simultaneously, it assists in the correlation of environmental and economic indicators.

Proposed research

- National material flow accounting for steel, paper and pulp, and coal, and integration of results to project regional perspective. Participating institutions will conduct national level material flows for steel, paper and pulp, and coal using input–output models. The analysis will be done on weight basis of the material. Material flow analysis will be able to determine
  - production intensity of different types of products
  - product consumption patterns in major sectors (e.g., steel is used in automobile, construction, consumer product, etc.) and their market share in each sector
  - inventory of residual wastes and emissions (air, water, solid, and hazardous) from initial extraction till final disposal
  - international trade of materials and its effect on economy and environment
  - re-entrant fractions (recycled/reuse) to the economy
  - energy consumption during material flow and its implications
- Assessment of environmental impacts of material flow at local, regional, and global levels
  - air (community exposure, acid rain, global warming)
  - water (toxicity, eutrophication)
  - wastes (solid/hazardous – collection and disposal)

  Impact assessment will be done on the basis of published data.
- Evaluation of the trends in industrial growth with respect to production capacity, technological advancements, and corresponding material consumption over a decade to highlight resource utilization and efficiency and analyse progress towards dematerialized societies.
- Policy and technological interventions to link the compatibility of material–environmental fluxes.

Production systems

Economic progress and national wealth of a country are measured solely in terms of gross domestic product. Economic policies still aim at increasing labour productivity and production volume. But large-scale production activity does not translate into wealth or better human welfare unless the externalities causing damage to ecosystems are reduced appreciably or completely eliminated. The stratagem to rekindle the industry out of the economic and resource crunch is to initiate the practice of industrial metabolism. The catalysts required to carry out the transformation reactions have to imitate their counterparts found in nature, which comprehend the principle of *wastes equals resource*. The Business Council for Sustainable Development have proposed eco-efficiency as a tool to produce goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity through the life cycle to a level at least in line with the earth's estimated carrying capacity. The notion of eco-efficiency will evolve as a function of innovation, customer values, and economic policy instruments (Fussler 1994).

Proposed research

- Assessment of current production technology in practice with respect to
    - pollution abatement
    - water and energy conservation
    - production cost

  Assessment will be done on the basis of the published benchmarks and standards for different production processes.
- Feasibility of appropriate clean production technology to replace the existing technology and the institutional barriers / technical know-how / government policies hindering the technology transfer.
- Determination of the extent of the use of recycled materials and better substitutes as inputs to reduce environmental damage and produce less material intensive products.
- Identification of options to recognize wastes as resources by virtue of recycling, reuse, repair, or re-manufacturing (e.g. packaging material).
- Development of suitable metrics to highlight material efficiency and waste utilization (e.g., material recycling index, raw material depletion).

Consumption systems

Business corporations all over the world have begun with a holistic approach to examine very closely the social effects of their operations and activities. Relationships with and obligations to the communities are entering a new phase because local stakeholders and consumers demand more environment friendly goods and services produced by social responsible companies. Savvy consumers are able to influence the production and supply chain of products. Sustainable consumption is as important as sustainable production process to minimize product usage and hence waste generation. The torpid transformation of consumer–product link from 'product of consumption' to 'product of service' is an encouraging indication (McDonough 1998). The concept is to lease a product rather than own it and return it to the industry after use instead of dumping it. Besides a technological approach in designing sustainable products, a behavioural science thrust is needed to supplement and accelerate industrial transformation research. Vacillating human behaviour is the eventual arbitrator to decide the fate of the producer. Policy interventions to promote industrial transformation are effective only if the target audience accepts it. Thus, an understanding of human values, needs, choices, and circumstances is indispensable.

Proposed research

- Effectiveness of policy instruments to promote sustainable consumerism – several policy instruments like public procurement, 'green' marketing (IHDP Science Plan 1998) etc.; are in practice to influence consumer behaviour, but are limited to developed countries. Efficacy of these instruments in developing countries is still to be ascertained.
- Analysis of the consumption patterns in steel, paper and pulp, and coal (e.g., if consumers have shifted to use of recycled steel products or post consumer recycled paper) and its implications on environment.
- Role of consumer forums and associations in achieving consumer's needs and preferences for sustainable products.
- Development of suitable metrics to highlight sustainable consumer behaviour (e.g. consumer recycling index, post consumer waste generation).

Human dimension of proposed research

Development of a human dimension approach towards the growth of a sustainable society has been an arduous task for researchers and planners. The diversity and complexity of the issues involved usually hinder the approach for a unified framework. The IHDP, a forum of scientists and planners, has initiated efforts to develop a research framework that emphasizes the role of humans causing environmental change and its effects on social and economic processes. The proposed research is an effort to identify IHDP industrial transformation activities in steel, paper and pulp, and coal using material flow analysis tools and simultaneously examine the human and social aspects. Sub-species of human domain – producers, consumers, financiers, planners, policy makers, and researchers – have different desires and needs, but the impacts of materials flow are ubiquitous. The implicit objective of research would be to consolidate behavioural mechanisms that bring deterring human forces to a quasi-steady equilibrium. The final delivery point of research would be characterization of actions to implement industrial transformation activities in a synergistic and symbiotic environment for all human sub-components such that overall human needs and preferences are met.

References

Institute of Environmental Studies. 1998.
Industrial Transformation – Development of a Science Plan (Draft), Amsterdam.

Wernick I K and Ausubel J H. 1995.
National Materials Flows and the Environment. *Annual Review of Energy and the Environment,* **20**:463–492.

Fussler C. 1994.
The development of eco-efficiency in industry. *UNEP Industry and Environment,* **October–December**: 71–74.

Graedel T and Allenby P. 1995.
Industrial Ecology. John Wiley & Sons Pvt. Ltd.

McDonough W. 1998.
Keynote address to the Garden Club of America.

Programme

4 APRIL 1998

0900-0905 Welcome Address
Dr R K Pachauri, Director, TERI

0905-0915 Introduction of the IHDP-IT
Prof. Pier Vellinga, Director, Institute for Environmental Studies, The Netherlands

0915-0939 Inaugural Address
Mr S S Boparai K C, Secretary, Ministry of Non-Conventional Energy Sources, GoI

0930-0955 First Keynote Address
Dr R K Pachauri

0955-1010 COFFEE

Session-1 International issues related to IHDP-IT

Chairperson: Prof. Robert H Socolow, USA
Panellists: Prof. Pier Vellinga
Mr Katsuo Seiki, Japan
Dr Kulthorn Silapabanleng, Thailand

1010-1040 Second keynote address and discussion on 'Framework for industrial transformation'
Prof. Pier Vellinga

1040-1120 Third keynote address and discussion on 'Macroeconomic incentives'
Dr Shreekant Gupta, Delhi School of Economics, Delhi

1120-1200 Fourth keynote address and discussion on 'Technological change'
Prof. R H Socolow, Director, Center for Energy and Environmental Studies, Princeton University, Princeton, USA

1200-1240 Fifth keynote address and discussion on 'Consumption of energy and materials'
Dr Leena Srivastava, Dean, Policy Analysis Division, TERI

1300-1400 LUNCH

Session-2 Asian Perspective on IHDP-IT

1400-1615 Panel discussion on 'Issues in industrial transformation and research agenda for Asia'

Chairperson: Prof. Pier Vellinga
Panellists Dr Ijaz Hossain, Bangladesh
Dr Sitanon Jesdapipat, Thailand
Dr S Maudgal, India

1500-1515 COFFEE

1515-1615 Panel discussion on 'Issues in industrial transformation and research agenda for Asia' continued

5 APRIL 1998

Session-3 Development of research plans and priorities both for Asia and the world

0930-1230 Working groups

Group-1 Coal, energy, and materials flow
Group-2 Transport systems
Group-3 Rural and urban dimensions

1045-1100 COFFEE

1230-1330 LUNCH

1330-1400 Presentations by the working groups on summary of discussions

1400-1500 Plenary session - Implementation strategies and plans

Chairperson: Dr R K Pachauri
Panellists: Prof. Pier Vellinga
Prof. R H Socolow
Dr Ijaz Hossain
Mr Katsuo Seiki

1500-1530 COFFEE

1530-1600 Summing up

List of participants

Dr Y P Abbi
Executive Director (Corporate Engg.)
Corporate Office
Bharat Heavy Electricals Limited
BHEL House, Siri Fort
New Delhi - 110 049
Tel. +91 11 649 2821/649 3608
Fax +91 11 649 3310/649 2974

Mr Mozaharul Alam
Research Fellow
Bangaladesh Centre for Advanced Studies
House 23 (New) 620 (old), Road 10A (New)
Dhanmondi, GPO Box 3971
Dhaka, Bangladesh
Tel. +880 2 9119823, 9113682, 815829, 813977
Fax +880 2 811344, 818206
E-mail bcas@bdonline.com

Prof. S P Banerjee
178/4, Parnasree, Behala
Calcutta - 700 060
Tel. +91 33 2428492, 2422300 (off)
+91 33 4513182 (res)
Fax +91 33 2428153, 2428185 (off)

Ms Shankari Banerji
National Council of Applied Economic Research (NCAER)
Parisila Bhawan, 11, I P Estate
New Delhi - 110 002
Tel. +91 11 331 7860-68
Fax +91 11 332 7164

Mr Nguyen Van Binh
Dipl. Engineer
Institute for Industry Policy and Strategy
Ministry of Industry
54 Hai Ba Trung Str.
Hoan Kiem District
Ha noi, Vietnam
Tel. +84 4 8259844
Fax +844 8253417

Mr S S Boparai K C
Secretary
Ministry of Non-Conventional Energy Sources
Block No.14, C G O Complex
Lodhi Road
New Delhi 110 003
Tel. +91 11 436 1481
Fax +91 11 436 2772

Mr Pradeep K Dadhich
Fellow, Policy Analysis Division
TERI
Darbari Seth Block, Habitat Place
Lodhi Road
New Delhi - 110 003
Tel. +91 11 462 2246, 460 1550
Fax +91 11 463 2609, 462 1770
E-mail pdadhich@teri.res.in

Ms Uma Garud
Addl. Secretary
Federation of Indian Chambers of
Commerce and Industry (FICCI)
Federation House, Tansen Marg
New Delhi - 110 001
Tel. +91 11 331 5442, 373 8760 (D)
Fax +91 11 332 0714

Dr Carlos Gay
Instituto Nacional de Ecologia
Unidad de Cooperacion Y Convenios Internacioinales
AV. Revolucion 1425
Nievel 31, Torre Ejecutiva
Col. San Angel, C.P. 01040
Mexico, D.F.
Tel. +52 5 624 3542/45
Fax +52 5 624 3593
E-mail cgay@chajul.ine.gob.mx

Dr S P Ghosh
Director General
National Council for Cement and Building Materials
P-21, South Extension Part-II
New Delhi - 110 049
Tel. +91 11 625 9010, 625 0590, 643 4213
Fax +91 11 6422933

Dr Shreekant Gupta
Associate Professor
Department of Economics
Delhi School of Economics
Delhi - 110 007
Tel. +91 11 725 6533, 725 6535 (D), 725 6214 (D)
Fax +91 11 725 7159
E-mail sgupta@cdedse.ernet.in, gupta@sdalt.ernet.in

Dr Ijaz Hossain
Associate Professor
Chemical Engineering Department
Bangladesh University of Engineering & Technology
Dhaka – 1000
Bangladesh
Tel. +880 2 500254
Fax +880 2 811431, 863026, 863046
E-mail pmrebuet@bangla.net

Dr Sitanon Jesdapipat
Director, Natural Resources and Management Program
Thailand Environment Institute
210 Sukhumvit 64, Bangchak Refinery Building 4
Prakanong, Bangkok 10260
Thailand
Tel. +66 2 3310047, 3310060 extn. 4157
Fax +66 2 3324873, 66 7429697-8
E-mail sitanon@tei.or.th

Ms Wasantha Madurapperuma
Institute of Fundamental Studies (IFS)
Hantana Road
Kandy, Sri Lanka
Tel. +94 8 232002
Fax +94 8 232131
E-mail wasantha@ifs.ac.lk

Dr S Maudgal
Senior Adviser (Clean Technologies)
R.No.553, Fifth Floor
Ministry of Environment and Forests
Paryavaran Bhavan, CGO Complex
Lodhi Road, New Delhi - 110 003
Tel. +91 11 436 2827
Fax +91 11 436 0861, 436 0806

Dr Smita Misra
133, Vaishali
Pitampura
Delhi - 110 034
Tel. +91 11 741 2901, 725 3210

Dr R K Pachauri
Director
TERI
Darbari Seth Block, Habitat Place
Lodhi Road, New Delhi - 110 003
Tel. +91 11 462 7651, 464 7762
Fax +91 11 463 2609, 462 1770
E-mail pachauri@teri.res.in

Dr Anand Patwardhan
School of Management
Indian Institute of Technology
Powai, Mumbai - 400 071
Tel. +91 22 576 7788
Fax +91 22 578 3480
E-mail anand@cc.iitb.ernet.in

Mr M A Qureshi
Deputy Director
National Instt. of Science Tech. & Dev. Studies
Dr K S Krishnan Marg
New Delhi - 110 012
Tel. +91 11 572 8279 (Off)/223 1762 (Res)
Fax +91 11 575 1758, 575 4640

Dr Md Sufiur Rahman
First Secretary
Bangladesh High Commission
56, Ring Road, Lajpat Nagar-III
New Delhi
Tel. +91 11 683 4668
Fax +91 11 684 0596

Mr Ahmad Saeed
Coordinator
Environment Assessment Services
International Union for the
Conservation of Nature (IUCN)
1, Bath Island Road
Karachi – 75530, Pakistan
Tel. +92 21 586 1540
Fax +92 21 5870287, 5861448
E-mail as@iucn.khi.sdnpk.undp.org

Dr Ambuj Sagar
Post-Doctoral Fellow
Centre for Science and International Affairs
John F Kennedy School of Government
Harvard University, 79 John F Kennedy Street
Cambridge, MA 02138, U.S.A.
Tel. +1 617 496 6218
Fax +1 617 495 8963
E-mail ambuj_sagar@harvard.edu

Mr S Naushab Sarwar
Manager
Hydrocarbon Development Institute of Pakistan
48J Block-6, Pechs
Karachi, Pakistan
Tel. +92 21 4529476 (off)/5842982 (res)
Fax +92 21 4535592
E-mail mko@hdipt.isb.erum.com.pk

Mr Katsuo Seiki
Executive Director
Global Industrial & Social Program
Research Institute
3rd Floor, Shousen-Mitsui Bldg
2-1-1, Toranomon
Minato-Ku, Tokyo 105, Japan
Tel. +81 35563 8800
Fax +81 35563 8810
E-mail seiki@blue.ocn.ne.jp

Prof. Manubhai Shah
Managing Trustee
Consumer Education and Research Centre (CERC)
Suraksha Sankool, Thaltej
Ahmedabad-Gandhinagar Highway
Ahmedabad - 380 054
Tel. +91 79 7489945-46, 7450528, 7451097
Fax +91 79 7489947
E-mail cerc@ad1.vsnl.net.in

Dr Kulthorn Silapabanleng
Director, Energy Research Institute
Chulalongkorn University
Phyathai Road, Bangkok 10330
Thailand
Tel. +66 2 2188096-9
Fax +66 2 2547579
E-mail fengksl@chulkn.car.chula.ac.th

Dr R K Singh
Director (Chemicals)
Bureau of Indian Standards (BIS)
Manak Bhavan
9, Bahadurshah Zafar Marg
New Delhi - 110 002
Tel. +91 11 3230131
Fax +91 11 3236902, 3234062, 3239399

Prof. Robert H Socolow
Director, Center for Energy and Environmental Studies
H 102 Engineering Quadrangle
Princeton University
Princeton, NJ 08544, U.S.A.
Tel. +1 609 258 5446 (off)/921 9061 (res)
Fax +1 609 258 3661
E-mail socolow@princeton.edu

Mr P V Sridharan
Senior Fellow
Policy Analysis Division
TERI
Darbari Seth Block, Habitat Place
Lodhi Road, New Delhi - 110 003
Tel. +91 11 462 2246, 460 1550
Fax +91 11 463 2609, 462 1770

Mr D S R K Srinivas
Research Associate
Energy-Environment Interface Group
TERI
Darbari Seth Block, Habitat Place
Lodhi Road, New Delhi - 110 003
Tel. +91 11 462 2246, 460 1550
Fax +91 11 463 2609/4621770
E-mail dsrk@teri.res.in

Dr Leena Srivastava
Dean, Policy Analysis Division
TERI
Darbari Seth Block, Habitat Place
Lodhi Road, New Delhi - 110 003
Tel. +91 11 462 2246, 460 1550
Fax +91 11 463 2609, 462 1770
E-mail leena@teri.res.in

Dr Nguyen Van Tai
Policy Division
National Environmnet Agency
Ministry of Science, Technology and Environment
39 Tran Hung Dao
Ha noi - VIETNAM
Tel. +84 4 8424511
Fax +84 4 8242510, 8248932

Mr Lalit Kumar Vaidya
Senior Divisional Chemist (Deputy Director)
Nepal Bureau of Standards and Metrology
Kathmandu, Nepal
Tel. +977 1 350818, 350447 (off), 222286, 243678 (res)
Fax +977 1 350689 (off)

Prof. Pier Vellinga
Director
Institute for Environment Studies (IVM)
Vrije Universiteit, De Boelelaan 1115
1081 HV Amsterdam, The Netherlands
Tel. +31 20 4449 555
Fax +31 20 4449 553
E-mail pier.vellinga@ivm.vu.nl

Mr Robert O Williams
Senior Industrial Development Officer
Industrial Energy Efficiency Branch
UNIDO, Vienna International Centre
Vienna, Austria
Tel. +43 1 21 1313956
Fax +43 1 21 1316803
E-mail rwilliams@unido.org